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Authors

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EDITOR & AUTHORS PROFILE

They have sufficient teaching and research experience with expertise in Animal physiology. They have published sufficient books for the benefits of undergraduate and postgraduate students.

Editor

Dr. M. Charumathy., M.Sc., M.Phil. Ph D.
Assistant Professor
Department of Biochemistry
Marudhar Kesari Jain College for Women, Vaniyambadi

Chapter No	Author's Profile
1.	**Mrs. M.Ayesha Sabeen., M.Sc., M.Phil.,** Assistant Professor & Head, Department of Biochemistry, Vivekanandha Arts and Science College for Women, Veerachipalayam, Sankari West post Salem District, Tamil Nadu. E.Mail: ayeshachemistry14@gmail.com
2.	**Mrs. M. Anuradha, M.Sc., M.Phil.,** Assistant Professor, Department of Zoology, Auxilium College (Autonomous), Gandhi Nagar, Vellore District, Tamil Nadu. E.mail: anu.m1477@gmail.com

3.	**P. Arputharaj M.Sc.** Research Scholar Dept. Adv. Zoology & Biotech Loyola College, Chennai E.Mail: arputharaj.9111@gmail.com
4.	**Mrs.P. Kousalya., MSc., M.Phil.,** Assistant Professor, PG and Research Department of Biochemistry, Bharathidasan College of Arts and Science, Ellispettai,Pallapalayam (PO), Erode-638116, Tamil Nadu, India. E.mail: kousiviswa@gmail.com
5.	**Dr. G. Abi Beaulah, M.Sc., MPhil., SET., PhD** Head & Assistant Professor, Department of Biochemistry Auxilium College (Autonomous), Gandhi Nagar, Vellore, Tamil Nadu, India

PREFACE

The first edition of “Textbook of Animal Physiology” this book was written to help students to learn the animal organ and its system of knowledge needed to successfully understanding of Human Physiology.

“Physiology” is the scientific study of functions and mechanisms in a living system. As a sub-discipline of biology, physiology focuses on how organisms, organ systems, individual organs, cells, and biomolecules carry out the chemical and physical functions in a living system.

We welcome comments by readers of “Textbook of Animal Physiology” for ways to improve the book and to increase its value. Such suggestions will be seriously considered in the preparation of subsequent editions.

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CHAPTER - I

NUTRITION

Nutrition - nutrients - digestion and absorption of proteins, carbohydrates and lipids. Role of gastrointestinal hormones indigestion.

Mrs. M. AYESHA SABEEN., M.Sc., M.Phil.,
Assistant Professor & Head,
Department of Biochemistry,
Vivekanandha Arts and Science College for Women,
Salem District, Tamil Nadu.
E.Mail: ayeshachemistry14@gmail.com

Physiology is the study of the functions of the organs and the organ systems of the living systems. For instance, the physiology of digestive system refers to the study of digestion, the physiology of kidney refers to the study of excretion and so on.

The functional study of any organ or organ system is closely linked with its morphology and anatomy.

NUTRITION

Nutrition is defined as the processes by which an animal or plant takes in and utilizes food substances. It is a critical part of health and development.

Essential nutrients include protein, carbohydrate, fat, vitamins, minerals and electrolytes.

Nutrition is the science that interprets the nutrients and other substances in food in relation to maintenance, growth, reproduction, health and disease of an organism.

NUTRIENTS

Nutrients are the compounds in food that provide us with energy that facilitates repair and growth and helps to carry out different life processes.

Essential nutrients are compounds that the body can't make or can't make in sufficient quantity.

According to the World Health Organization, these nutrients must come from food, and they're vital for disease prevention, growth, and good health.

Not all nutrients provide energy but are necessary for some form or the other. These nutrients are divided into two categories:

- Macronutrients, which are required by the body in large amounts.
- Micronutrients, which are required by the body in small amounts.

MACRONUTRIENTS

Macronutrients are eaten in large amounts and include the primary building blocks of the diet.

Macronutrients provide energy to a living being for the function of the metabolic system. They provide massive energy has it is converted used to obtain energy. Macronutrients include fats, proteins, and carbohydrates.

MICRONUTRIENTS

Micronutrient provides essential components for metabolism to be carried out. They also build and repair damaged tissues in order to control the body process.

Micronutrients include calcium, iron, vitamins, iron, minerals and vitamin C.

FUNCTIONS OF NUTRIENTS

The important functions of nutrients include:

- They are the main source of energy for the body.
- They help in building and repairing body tissues.
- Increases the absorption of fat-soluble vitamins.
- Helps in the synthesis of collagen.
- Provides proper structure to the blood vessels, bones and ligaments.
- They also help in maintaining the homeostasis of the body.

CARBOHYDRATES

It is one of the main sources of energy for human beings. It comprises of three types of carbohydrates and they include fibre, sugar, and starch. They are usually low calories and thus help in maintaining a healthy diet.

Carbohydrate is defined as an organic compound that contains carbonyl group, namely aldehyde or ketone in addition to two or more alcohol groups or that yields such compounds on hydrolysis.

Examples: Glucose, fructose, Sucrose, Lactose, Starch, Cellulose.

PHYSIOLOGICAL ROLE OF CARBOHYDRATES

1. Carbohydrates are the primary energy producers.
2. It plays an important role in metabolism.
3. It forms the main source of reserve food e.g., Starch, glycogen etc
4. It will prevent the degradation of skeletal muscle and other tissues such as the heart, liver, and kidneys.
5. Carbohydrates is basically the main fibre of the diet or provide the bulk fibre for better digestion.
6. Carbohydrates form a part of genetic material like DNA and RNA in the form of deoxyribose and ribose sugars.
7. It plays important roles in cellular recognition processes.

PROTEINS

The term 'Protein' is derived from a Greek word 'Proteos' meaning 'prime' or 'first importance'. Proteins are complex organic nitrogenous compounds. They contain C, H_2, O_2, N_2 and S.

Proteins are defined as high molecular weight polymers in which the building blocks are the amino acids. Each protein is formed of several amino acids.

PHYSIOLOGICAL ROLE OF PROTEINS

1. Protein has a critical physiological function. It is primarily used in the body to build, maintain and repair body tissues.
2. Protein is involved in the creation of some hormones, help control body functions that involve the interaction of several organs and help regulate cell growth.
3. Proteins supply energy and heat.
4. Nucleoproteins form important constituent of genes.
5. Protein help store other substance in the organism. For example, iron is stored in the liver in a complex with the protein ferritin.

LIPIDS

The lipids are a heterogeneous group of compounds, including fats, oils, steroids, waxes, and related compounds, that are related more by their physical than by their chemical properties.

They have the common property of being (1) relatively insoluble in water and (2) soluble in nonpolar solvents such as ether and chloroform.

They are important dietary constituents not only because of the high energy value of fats, but also because essential fatty acids and fat-soluble vitamins and other

lipophilic micronutrients are contained in the fat of natural foods.

Chemically, lipids are either asters of fatty acid or substances capable of forming such esters.

PHYSIOLOGICAL ROLE OF LIPIDS

1. Lipids serve as the main source of energy in organisms.
2. They are responsible for cell permeability and cell organization.
3. Lipids containing phosphorus as part of their structures (phospholipids) help to transport other lipids in the blood.
4. Phospholipids are the major structural components of cell membranes, where they control the transport of nutrients into and out of the cells.
5. Fats provide support for many organs in the body such as heart, kidney and intestine.

VITAMINS

Vitamins are a group of substances that are needed for normal cell function, growth, and development. Vitamins are defined as potent organic compounds occurring in varying and minute proportions in food, which must be available to the organism from exogenous sources, in order

to that physiological processes essential to life may proceed normally.

Vitamins are classified into two groups according to their solubility. They are fat soluble vitamins and water-soluble vitamins.

Fat soluble vitamins are Vitamin A, Vitamin D, Vitamin E and Vitamin K. Water soluble vitamins are Vitamin B complex and Vitamin C.

FAT SOLUBLE VITAMINS

VITAMIN A

Vitamin A; includes retinol, retinal, retinyl esters, and retinoic acid and are also referred to as "preformed" vitamin A. Beta carotene can easily be converted to vitamin A as needed.

BIOLOGICAL FUNCTIONS

1. Essential for vision Lycopene may lower prostate cancer risk.
2. Keeps tissues and skin healthy.
3. Plays an important role in bone growth and in the immune system.
4. Diets rich in the carotenoids alpha carotene and lycopene seem to lower lung cancer risk.

5. Carotenoids act as antioxidants. Foods rich in the carotenoids lutein and zeaxanthin may protect against cataracts.

RECOMMENDED DIETARY ALLOWANCE

M: 900 mcg (3,000 IU)W: 700 mcg (2,333 IU)

FOOD SOURCES

Sources of retinoids: beef liver, eggs, shrimp, fish, fortified milk, butter, cheddar cheese, Swiss cheese

Sources of beta carotene: sweet potatoes, carrots, pumpkins, squash, spinach, mangoes, turnip greens.

DEFICIENCY DISEASES

1. In children, deficiency of Vitamin A retards growth, leading to loss of weight.
2. Deficiency of Vitamin A leads to night blindness. Vision in dim light is carried out by the rhodopsin pigment present in the retina of eye. Vitamin A is essential for the synthesis if rhodopsin.
3. The deficiency leads to reddening, dryness and lusterless condition of eye called as xerophthalmia.
4. In extreme cases of deficiency, the cornea becomes soft, disorganized and destroyed. This defect is called Keratomalacia.

VITAMIN D (Calciferol, Sunshine Vitamin)

Vitamin D is formed by the irradiation of sterols. The skin of man contains large amounts of cholesterol. This is converted into Vitamin D on exposure to sunlight.

BIOLOGICAL FUNCTIONS

1. Vitamin D helps in the maintenance of normal blood levels of calcium and phosphorus, which strengthen bones.
2. Helps form teeth and bones. Supplements can reduce the number of non-spinal fractures.
3. It is essential for calcium metabolism.
4. It helps in the deposition of calcium and phosphates in the bones.

RECOMMENDED DIETARY ALLOWANCE

31–70: 15 mcg (600 IU) 71+: 20 mcg (800 IU)

FOOD SOURCES

Fortified milk or margarine, fortified cereals, fatty fish

DEFICIENCY DISEASE

Vitamin D deficiency can lead to a loss of bone density, which can contribute to osteoporosis and fractures (broken bones).

Severe vitamin D deficiency can also lead to other diseases.

In children, it can cause rickets. Rickets is a rare disease that causes the bones to become soft and bend.

In adults, severe vitamin D deficiency leads to osteomalacia. Osteomalacia causes weak bones, bone pain, and muscle weakness.

VITAMIN E (Tocopherol)

The word 'tocopherol' is derived from two Greek words namely, tokos = Childbirth, phero = to bear. It is necessary for the fertility of male and the birth process of female.

BIOLOGICAL FUNCTIONS

1. Acts as an antioxidant, neutralizing unstable molecules that can damage cells.
2. Protects vitamin A and certain lipids from damage. Diets rich in vitamin E may help prevent Alzheimer's disease.
3. Essential for the normal functioning of muscles, and for the biosynthesis of Co-enzyme Q.

RECOMMENDED DIETARY ALLOWANCE

M: 15 mg, W: 15 mg (15 mg equals about 22 IU from natural sources of vitamin E and 33 IU from synthetic vitamin E).

FOOD SOURCES

Wide variety of foods, including vegetable oils, salad dressings and margarines made with vegetable oils, wheat germ, leafy green vegetables, whole grains, nuts

DEFICIENCY DISEASE

1. In the female rat, the foetus dies sometime after implantation. This defect is called resorption sterility. Prolonged deficiency in female leads to loss of ability to conceive.
2. In male, prolonged deficiency leads to the degeneration of testis and permanent sterility.
3. Deficiency leads to necrosis of heart muscles.
4. Other diseases include, muscular dystrophies, peripheral vascular disorders, heart disorders and menopause.

VITAMIN K (Anti haemorrhagic Vitamin)

Vitamin K (Phylloquinone) is a fat soluble vitamin, essential for blood clotting.

BIOLOGICAL FUNCTIONS

1. Activates proteins and calcium essential to blood clotting. May help prevent hip fractures
2. It is essential for the synthesis of prothrombin which is essential for the coagulation of blood.

RECOMMENDED DIETARY ALLOWANCE

M: 120 mcg, W: 90 mcg

FOOD SOURCES

Cabbage, liver, eggs, milk, spinach, broccoli, sprouts, kale, collards, and other green vegetables

DEFICIENCY DISEASE

When Vitamin K is deficient, coagulation is prevented, when there occurs an injury, generally bleeding is stopped within 5 to 8 minutes. This is due to coagulation of blood on the wound surface. When Vitamin K is deficient coagulation does not occur. This leads to continuous bleeding from the wound and the victim dies because of loss of blood.

WATER SOLUBLE VITAMINS

Water-soluble vitamins travel freely through the body, and excess amounts usually are excreted by the kidneys. The body needs water-soluble vitamins in frequent, small doses.

These vitamins are not as likely as fat-soluble vitamins to reach toxic levels. But niacin, vitamin B6,

folate, choline, and vitamin C have upper consumption limits.

Vitamin B6 at high levels over a long period of time has been shown to cause irreversible nerve damage.

A balanced diet usually provides enough of these vitamins.

The following are the water soluble vitamins

Water Soluble Vitamins	
Vitamin:	Name:
B1	Thiamine
B2	Riboflavin
B3	Niacin
B5	Pantothenic Acid
B6	Pyridoxine
B7	Biotin
B9	Folate
B12	Cobalamin
C	Ascorbic Acid

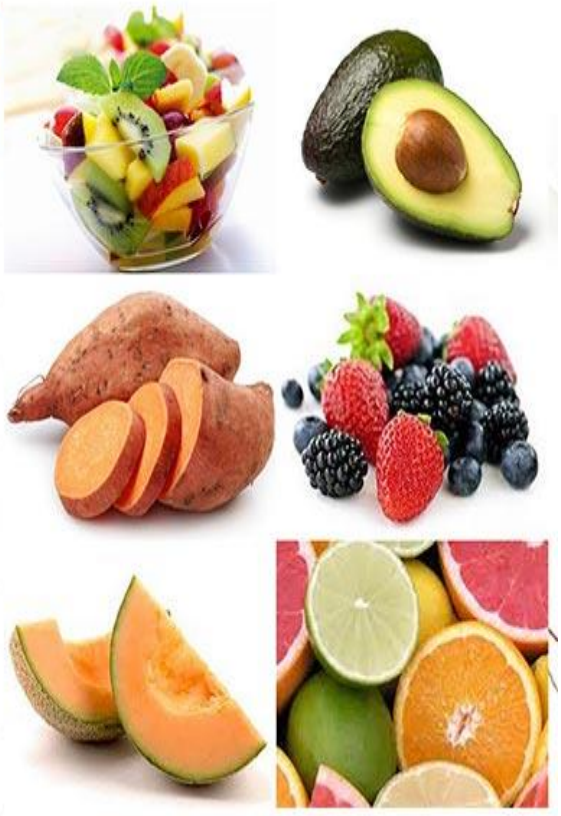


Fig 1: Water Soluble Vitamins

Vitamin	RDA/ AI		Best Sources	Functions
	Men	Women		
Thiamin (B1)	1.2mg	1.1mg	Fortified cereals and oatmeals, meats, rice and pasta, whole grains, liver	Helps the body release energy from carbohydrates during metabolism; growth and muscle tone
Riboflavin	1.3mg	1.1mg	Whole grains, green leafy vegetables, organ meats, milk, eggs	Helps the body release energy from protein, fat, and carbohydrates during metabolism
Niacin	16mg	14mg	Meat, poultry, fish, enriched cereals, peanuts, potatoes, dairy products, eggs	Involved in carbohydrate, protein, and fat metabolism
Pantothenic acid	5mg	5mg	Lean meats, whole grains, legumes	Helps release energy from fats and vegetables
Folate	400ug	400ug	Green leafy vegetables, organ meats, dried peas, beans, lentils	Aids in genetic material development; involved in red blood cell production
B6	1.3mg	1.3mg	Fish, poultry, lean meats, bananas, prunes, dried beans, whole grains, avocados	Helps build body tissue and aids in metabolism of protein
B12	2.4ug	2.4ug	Meats, milk products, seafood	Aids cell development, functioning of the nervous system, and the metabolism of protein and fat
Biotin	30ug	30ug	Cereal/grain products, yeast, legumes, liver	Involved in metabolism of protein, fats, and carbohydrates
Vitamin C	90mg	75mg	Citrus fruits, berries, and vegetables-especially peppers	Essential for structure of bones, cartilage, muscles, and blood vessels; helps maintain capillaries and gums and aids in absorption of iron.

Fig 2: Sources & functions of Water Soluble Vitamins

MINERALS

Minerals are those elements on the earth and in **foods** that our bodies need to develop and function normally.

Those essential for health include calcium, phosphorus, potassium, sodium, chloride, magnesium, iron, zinc, iodine, chromium, copper, fluoride, molybdenum, manganese, and selenium.

The body needs many minerals; these are called essential minerals.

Essential minerals are sometimes divided up into major minerals (macrominerals) and trace minerals (microminerals).

These two groups of minerals are equally important, but trace minerals are needed in smaller amounts than major minerals.

The amounts needed in the body are not an indication of their importance.

A balanced diet usually provides all of the essential minerals.

MACROMINERALS

Major minerals

Mineral	Function	Sources
Sodium	Needed forproper fluid balance, nerve transmission, and muscle contraction	Table salt, soy sauce; large amounts in processed foods; small amounts in

		milk, breads, vegetables, and unprocessed meats
Chloride	Needed for proper fluid balance, stomach acid	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, meats, breads, and vegetables
Potassium	Needed for proper fluid balance, nerve transmission, and muscle contraction	Meats, milk, fresh fruits and vegetables, whole grains, legumes
Calcium	Important for healthy bones and teeth; helps muscles relax and contract; important in nerve functioning, blood clotting, blood pressure regulation, immune system health	Milk and milk products; canned fish with bones (salmon, sardines); fortified tofu and fortified soy milk; greens (broccoli, mustard greens); legumes
Phosphorus	Important for healthy bones and teeth; found in every cell; part of the system that maintains acid-base balance	Meat, fish, poultry, eggs, milk, processed foods (including soda pop)
Magnesium	Found in bones; needed for making protein, muscle contraction, nerve transmission, immune system health	Nuts and seeds; legumes; leafy, green vegetables; seafood; chocolate; artichokes; "hard" drinking water

Sulfur	Found in protein molecules	Occurs in foods as part of protein: meats, poultry, fish, eggs, milk, legumes, nuts

TRACE MINERALS (MICROMINERALS)

The body needs trace minerals in very small amounts. **Iron** is considered to be a trace mineral, although the amount needed is somewhat more than for other microminerals.

Trace minerals		
Mineral	**Function**	**Sources**
Iron	Part of a molecule (hemoglobin) found in red blood cells that carries oxygen in the body; needed for energy metabolism	Organ meats; red meats; fish; poultry; shellfish (especially clams); egg yolks; legumes; dried fruits; dark, leafy greens; iron-enriched breads and cereals; and fortified cereals
Zinc	Part of many enzymes; needed for making protein and genetic material; has a function in taste perception, wound healing, normal	Meats, fish, poultry, leavened whole grains, vegetables

	fetal development, production of sperm, normal growth and sexual maturation, immune system health	
Iodine	Found in thyroid hormone, which helps regulate growth, development, and metabolism	Seafood, foods grown in iodine-rich soil, iodized salt, bread, dairy products
Selenium	Antioxidant	Meats, seafood, grains
Copper	Part of many enzymes; needed for iron metabolism	Legumes, nuts and seeds, whole grains, organ meats, drinking water
Manganese	Part of many enzymes	Widespread in foods, especially plant foods
Fluoride	Involved in formation of bones and teeth; helps prevent tooth decay	Drinking water (either fluoridated or naturally containing fluoride), fish, and most teas
Chromium	Works closely with insulin to regulate blood sugar (glucose) levels	Unrefined foods, especially liver, brewer's yeast, whole grains, nuts, cheeses
Molybdenum	Part of some enzymes	Legumes; breads and grains; leafy greens; leafy, green

		vegetables; milk; liver

DIGESTION

The food materials taken into the alimentary canal undergo a complicated process which converts the complex and insoluble food materials into simple and soluble food materials. This process is called digestion**.**

Digestion is defined as a process that involves physical and chemical breakdown of insoluble complex food materials into soluble simple food materials that can be absorbed and used as nutrients by the body.

Most of the substances in the diet cannot be utilized as such. These substances must be broken into smaller particles, then only these substances can be absorbed into blood and distributed to various parts of the body for utilization.

During digestion, carbohydrate is converted into glucose, proteins are converted into amino acids, and lipids are converted into fatty acids and glycerol.

Carbohydrates ----------→ Glucose

Proteins ----------→ Amino acids

Lipids ----------→ Fatty acids + glycerol

Digestion involves two processes, namely physical or mechanical and chemical.

DIGESTIVE SYSTEM OF MAN

Digestive system is made up of gastrointestinal tract (GI tract) or alimentary canal and accessory organs which help in the process of digestion and absorption.

GI tract is a tubular structure extending from the mouth up to anus with a length of about 30 feet. It opens to the external environment at both ends.

GI tract is formed by two types of organs

1. Primary digestive organs
2. Accessory digestive organs

1. Primary Digestive Organs

Primary digestive organs are the organs where actual digestion takes place. These organs are

i) Mouth

ii) Pharynx

iii) Oesophagus

iv) Stomach

v) Small intestine

vi) Large intestine

2. Accessory Digestive Organs

Accessory digestive organs are the organs which help the primary digestive organs in the process of digestion. These organs are

i) Teeth

ii) Tongue

iii) Salivary glands

iv) Exocrine part of pancreas

v) Liver

vi) Gall bladder

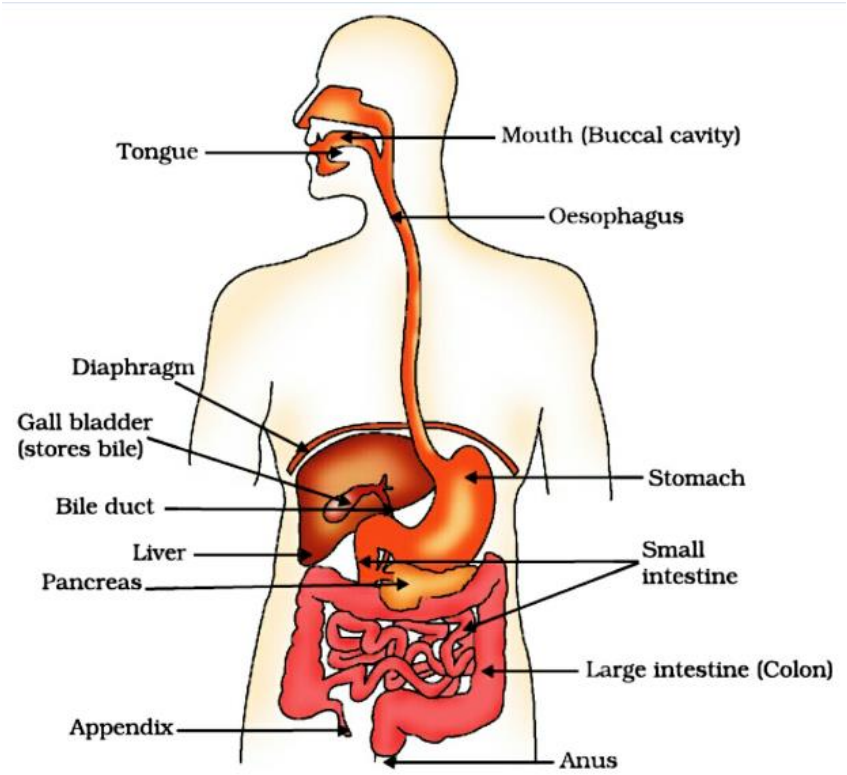


Fig 3 - Alimentary Canal of Man

The alimentary canal includes the teeth, mouth, tongue, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anus.

MOUTH

The mouth is surrounded by lips. The mouth cavity (buccal cavity or oral cavity) contains teeth and tongue. The total number of teeth is 32.

TONGUE

Tongue is a muscular organ. It is attached at the posterior end and free in the front. It contains numerous numbers of papillae and taste buds. Taste buds find out the taste of the food. The tongue is essential for mastication, deglutition, taste, speech and secretion of mucous.

PHARYNX

The pharynx is commonly called throat. Its main functions are transmission of air from nose to larynx, production of voice and transportation of food from mouth to oesophagus.

The pharynx is followed by oesophagus. It passes the food from pharynx to the stomach.

OESOPHAGUS

The oesophagus opens into the stomach. The junction of the oesophagus and stomach is called cardiac orifice. It is guarded by the cardiac sphincter.

STOMACH

The stomach is J – shaped. The inner surface of the curvature is called lesser curvature and the outer surface of the curvature is called greater curvature. The posterior end of the stomach opens into the small intestine by pyloric orifice. It is guarded by pyloric sphincter. The stomach has three regions, namely fundus, body and pylorus.

The fundus is the largest region. The lower part of fundus is separated from pylorus by a sharp angle on the lesser curvature called incisura angularies.

The pylorus has two regions namely, the proximal antrum and the distal pyloric canal which ends in pyloric sphincter.

SMALL INTESTINE

Stomach is followed by the small intestine. It has three regions. They are

i) Proximal part or duodenum

ii) Middle part or jejunum

iii) Distal part or ileum.

Small intestine is the part of GI tract extending between the pyloric sphincter of stomach and ileocecal valve, which opens into large intestine.

It is called small intestine because of its small diameter compared to that of large intestine, but it is longer than large intestine, about 25 feet (7.6 meters). The functional importance of small intestine is absorption.

The intestine is lined with mucous epithelium as in the stomach. The intestine contains three important structures. They are i) intestinal glands ii) folds of kercking iii) intestinal villi

INTESTINAL VILLI

The mucous membrane of small intestine is covered by minute finger like projections called villi.

The villi are lined by columnar cells, which are called enterocytes. Each enterocyte gives rise to hair like projections called microvilli.

Within each villus, there is a central channel called lacteal, which contains a milky fluid rich in fat. The lacteal opens into lymphatic vessels, and is surrounded by a network of capillaries, this in turn is surrounded by a layer

of mucous epithelial cells containing tall columnar epithelial cells and few goblet cells.

Digested lipids are absorbed into the lacteal and sugars and amino acids are absorbed into the capillaries, glucose and amino acids are absorbed by the blood capillaries and are transported through the portal system whereas fats, fatty acids and glycerol are absorbed by the lacteals and transported through the lymphatics.

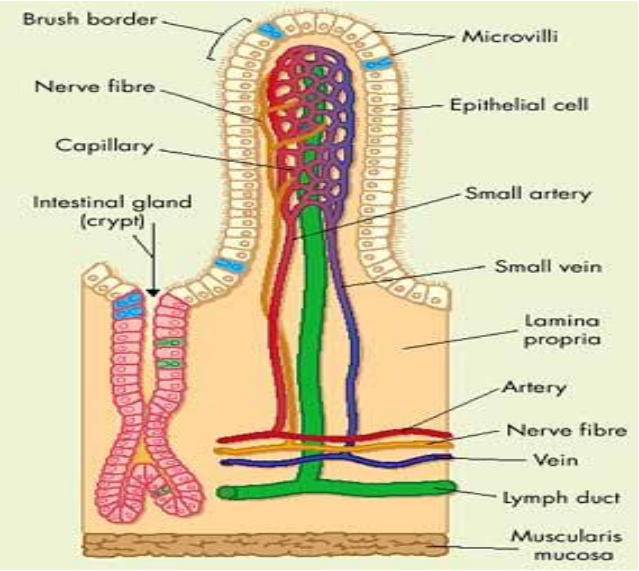


Fig 4 - Intestinal Villus

LARGE INTESTINE

The large intestine is also known as colon. It extends from ileocecal valve up to anus. It consists of seven portions

i) Cecum with appendix

ii) Ascending colon

iii) Transverse colon

iv) Descending colon

v) Sigmoid colon or pelvic colon

vi) Rectum

vii) Anal canal

The descending colon is followed by the rectum, which functions as a reservoir for the faeces. The rectum is followed by the anal canal. It opens to the outside through anus.

SECRETIONS OF DIGESTIVE TRACT

The alimentary tract produces a large variety and quantity of substances which contribute to digesting the food, and protecting and regulating the functions of the digestive tract.

All of these substances are secreted by either cells lining the digestive tract or by glands directly connected to the alimentary tract.

The various secretions of digestive system are

i) Saliva

ii) Gastric juice

iii) Pancreatic juice

iv) Bile

v) Intestinal juice

SALIVA

Digestive juice present in the mouth is saliva which is secreted by salivary glands.

Salivary glands

The salivary glands are present in the buccal cavity. In humans, the saliva is secreted by three pairs of major (larger) salivary glands and some minor (small) salivary glands in the oral and pharyngeal mucous membrane.

The major glands are

i) Parotid glands

ii) Submaxillary or submandibular glands

iii) Sublingual glands

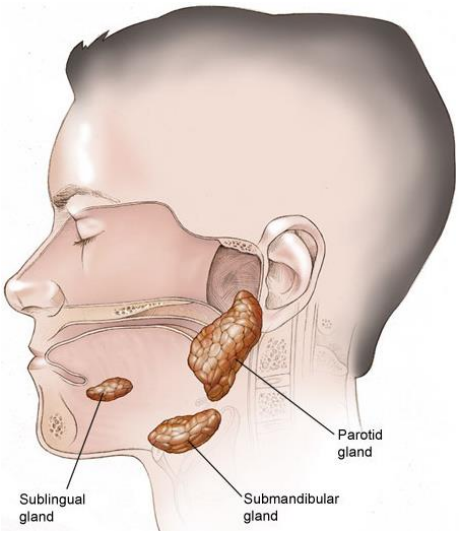


Fig 5 - Salivary glands in man

PAROTID GLANDS

Parotid glands are the largest of all salivary glands situated at the side of the face just below and in front of the ear.

SUBMAXILLARY GLANDS

Sub maxillary glands or submandibular glands are located in submaxillary triangle medial to mandible.

SUBLINGUAL GLANDS

These are the smallest salivary glands situated in the mucosa at the floor of mouth.

PROPERTIES AND COMPOSITION OF SALIVA

Properties of Saliva

1. Volume : 1,000 to 1500 ml of saliva is secreted per day and it is approximately about 1ml/min. Contribution by each major salivary gland is

i) Parotid glands : 25%

ii) Submaxillary glands : 70%

iii) Sublingual glands : 5%

2. Reaction : Mixed saliva from all the glands is slightly acidic pH of 6.35 to 6.85
3. Specific gravity: It ranges between 1.002 and 1.012.
4. Tonicity : Saliva is hypotonic to plasma

Composition of saliva

Mixed saliva contains 99.5% water and 0.5% solids.

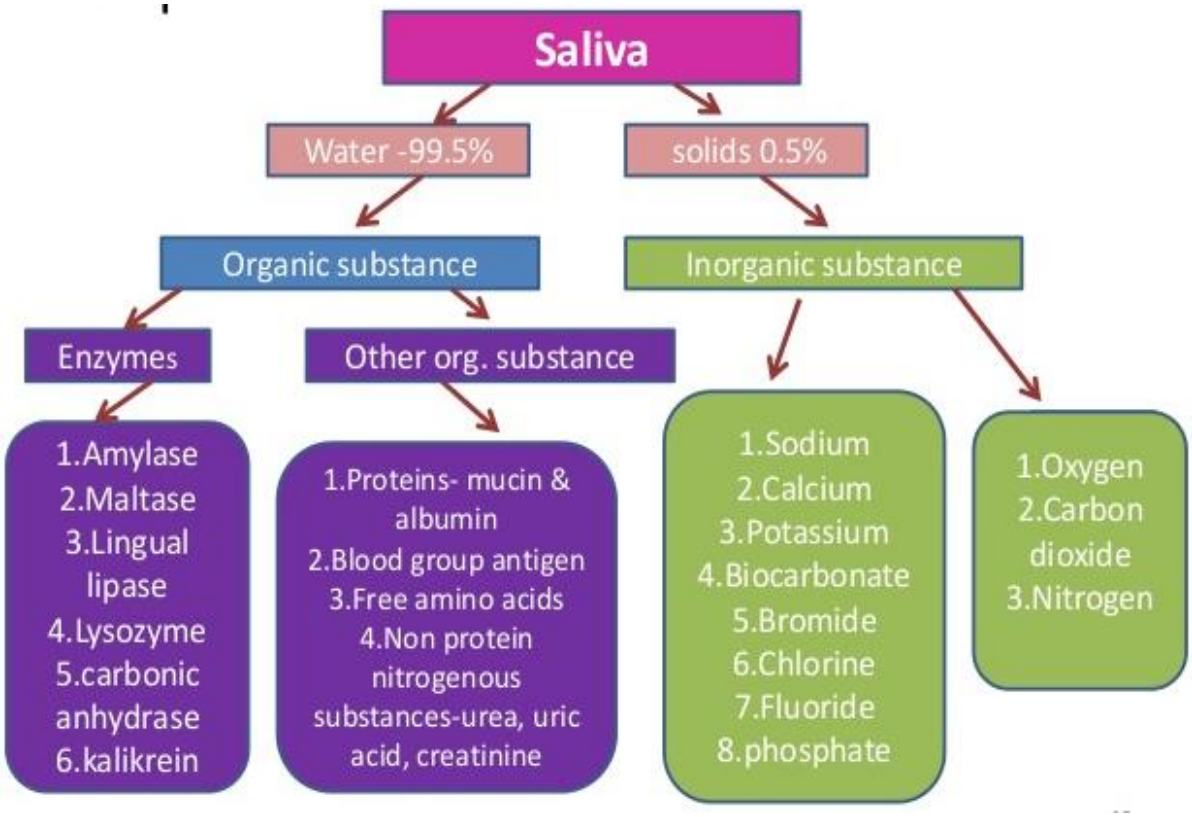


Fig 6 - Composition of Saliva

Functions of Saliva

Saliva is a very essential digestive juice. Since it has many functions, its absence leads to many inconveniences.

1. Preparation of food for swallowing

When food is taken into the mouth, it is moistened and dissolved by saliva. The mucous membrane of mouth is also moistened by saliva. It facilitates chewing.

By the movement of the tongue, the moistened and masticated food is rolled into a bolus. The mucin of saliva lubricates the bolus and facilitates the swallowing.

2. Appreciation of taste

Taste is a chemical sensation. Saliva, by its solvent action, dissolves the solid food substances, so that the dissolved substances can stimulate the taste buds. The stimulated taste buds recognize the taste.

3. Digestive function

The saliva has three digestive enzymes namely, salivary amylase, maltase and lingual lipase.

4. Cleansing and protective functions

The mouth and teeth are rinsed and kept free from food debris, shed epithelial cells and foreign particles due to the constant secretion of saliva. In this way, saliva prevents bacterial growth by removing materials, which may serve as culture media for the bacterial growth.

5. Role in speech

By moistening and lubricating soft parts of mouth and lips, saliva helps in speech. If mouth becomes dry, articulation and pronunciation become difficult.

6. Excretory function

Many substances, both organic and inorganic, are excreted in saliva. It excretes substances like mercury, potassium, iodide, lead and thiocyanate. Saliva also excretes some viruses such as those causing rabies and mumps.

GASTRIC JUICE

Stomach is a hollow organ situated just below the diaphragm on the left side in the abdominal cavity. Volume of empty stomach is 50ml.

PARTS OF STOMACH

1. Cardiac region
2. Fundus
3. Body or corpus
4. Pyloric region

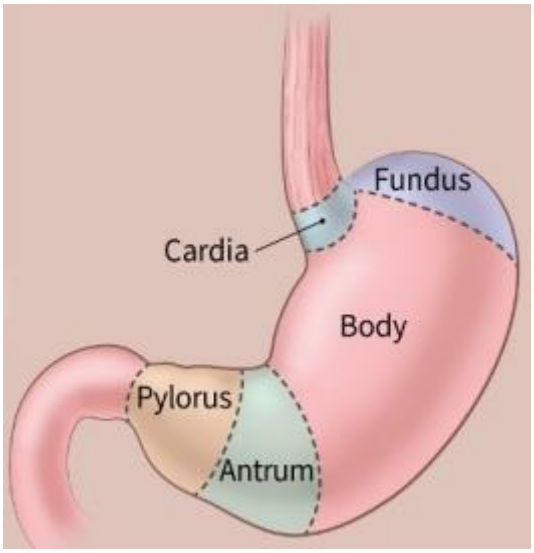


Fig 7 - Parts of Stomach

GLANDS OF STOMACH

Glands of stomach or gastric glands are tubular structures made up of different types of cells. These glands open into the stomach cavity through gastric pits.

Gastric glands are classified into three types depending upon their situation

1. Fundic glands

   These are situated in body and fundus of stomach. Fundic glands are also called main gastric glands or oxyntic glands

2. Pyloric glands

   This is present in the pyloric part of the stomach

3. Cardiac glands

   These are located in the cardiac region of stomach.

   All the gastric glands open into the cavity of stomach through gastric pits.

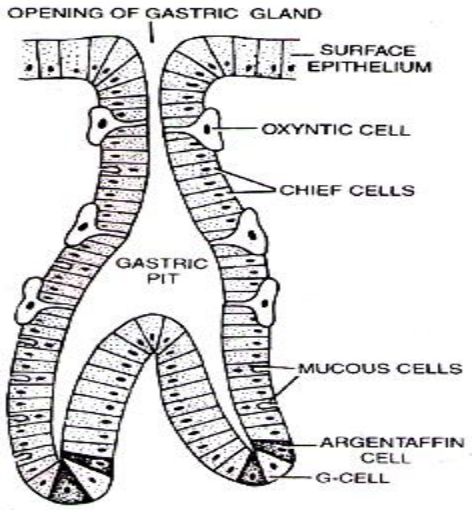


Fig 8 - Gastric glands

PROPERTIES AND COMPOSITION OF GASTRIC JUICE

Gastric juice is the mixture of secretions from different gastric glands.

Properties of gastric juice

1. Volume : 1,200 to 1,500 ml/day
2. Specific gravity : 1.002 to 1.004
3. Reaction: Gastric juice is highly acidic with pH of 0.9 to 1.2 due to hydrochloric acid.

Composition of gastric juice

Gastric juice contains 99.5% of water and 0.5% solids. The solids are organic and inorganic substances.

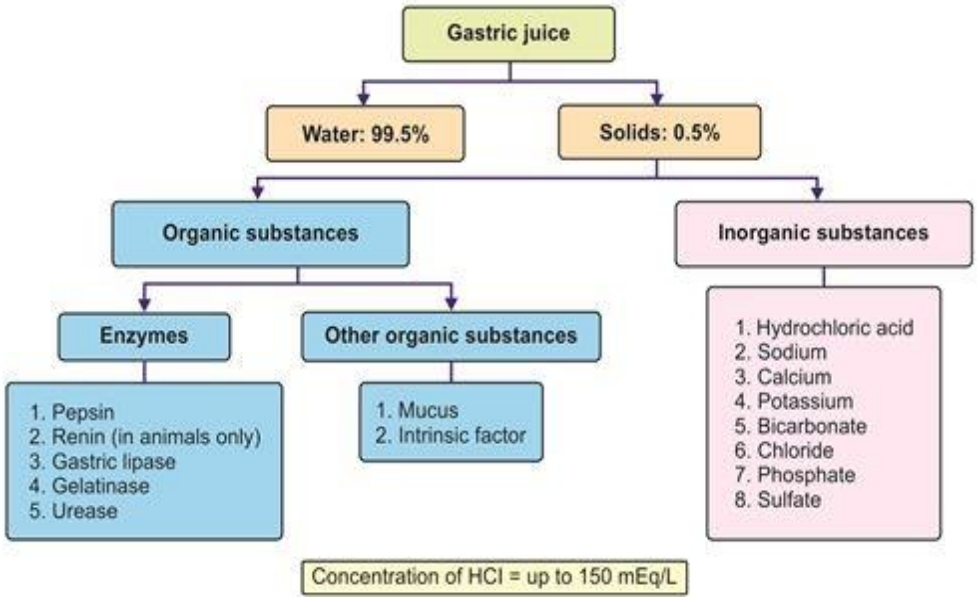


Fig 9 - Composition of gastric juice

Functions of gastric juice

1. Digestive function

   The gastric juice mainly on proteins. The proteolytic enzymes of the gastric juice are pepsin and rennin. Gastric juice also contains some other enzymes like gastric lipase, gelatinase, urase and gastric amylase.

2. Hemopoietic Function

   The intrinsic factor of Castle secreted by parietal cells of gastric glands plays an important role in erythropoiesis. It is necessary for the absorption of Vitamin B12 from GI tract into the blood.

3. Protective function

   The mucus present in the gastric juice protects the gastric wall from irritation or mechanical injury by virtue of its high viscosity.

4. Functions of Hydrochloric acid

   The hydrochloric acid present in the gastric juice activates pepsinogen into pepsin, kills some of the bacteria entering the stomach along with food substances.

PANCREATIC JUICE

Pancreas is a dual organ having two functions, the endocrine function and exocrine function. The endocrine

function is concerned with the production of hormones, whereas the exocrine function is concerned with the secretion of pancreatic juice.

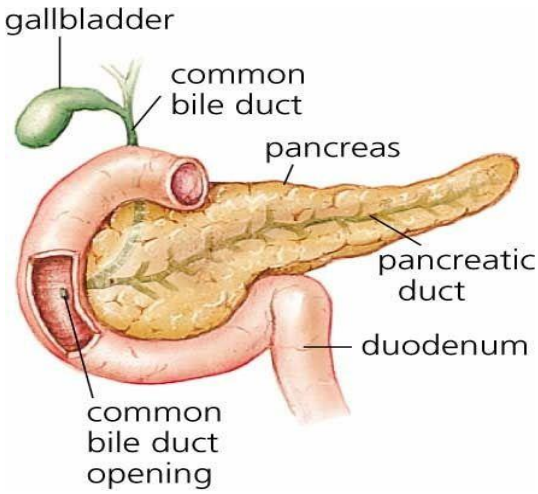


Fig 10 - Pancreas

PROPERTIES AND COMPOSITION OF PANCREATIC JUICE

Properties of Pancreatic juice

Volume: 500 to 8000 ml / day

Reaction: Highly alkaline with pH of 8 to 8.3

Specific activity: 1.010 to 1.018

Composition of pancreatic juice

Pancreatic juice contains 99.5% of water and 0.5% solids. The solids are the organic and inorganic substances.

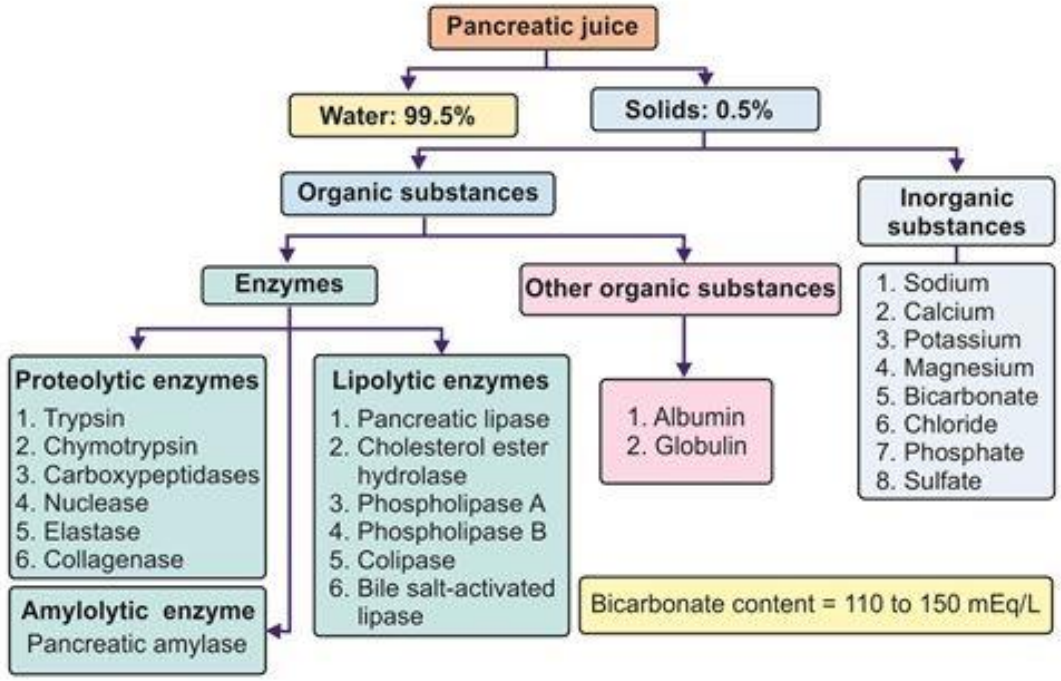


Fig 11 - Composition of Pancreatic juice

Functions of pancreatic juice

1. Digestive functions

   Pancreatic juice plays an important role in the digestion of proteins and lipids. It also has a mild action on carbohydrate digestion.

2. Neutralizing action

   When acid chyme enters intestine from stomach, pancreatic juice with large quantity of bicarbonate is released into intestine. Presence of large quantity of bicarbonate ions makes the pancreatic juice highly alkaline. This alkaline pancreatic juice neutralizes acidity of chime in the intestine.

Neutralizing action is an important function of pancreatic juice, because it protects the intestine from the destructive action of acid in the chyme.

BILE

Liver

Liver is a dual organ having both secretory and excretory functions. It is the largest gland in the body weighing about 1.5 kg in man. It is located in the upper and right side of the abdominal cavity immediately beneath diaphragm.

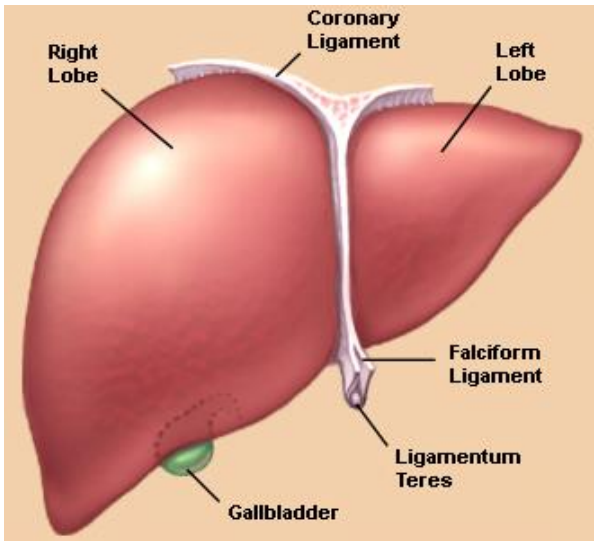


Fig12 - Liver

PROPERTIES AND COMPOSITION OF BILE

Bile is a golden yellow or greenish fluid. It enters the digestive tract along with pancreatic juice through the common opening called ampulla of vater.

Properties of bile

Volume: 800 to 1200 ml / day

Reaction: alkaline

pH: 8 to 8.6

Specific gravity: 1.010 to 1.011

Composition of bile

Bile contains 97.6% of water and 2.4% of solids. Solids include organic and inorganic substances.

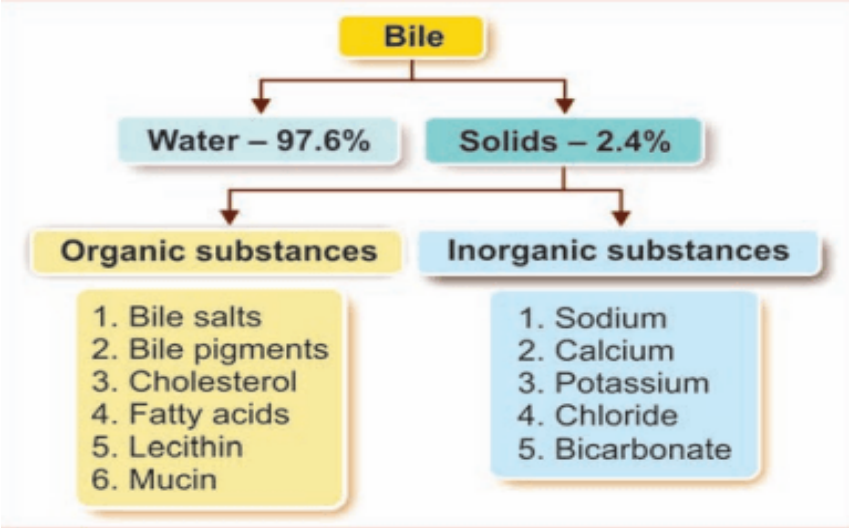


Fig 13 - Composition of bile

Functions of bile

1. Digestive function

Fats cannot be digested directly by lipolytic enzymes of GI tract, because the fats are insoluble in water due to the surface tension. The bile salts reduce the surface tension of the fats due to their detergent action.

2. Absorptive function

Bile salts help in the absorption of digested fats from intestine into blood. The bile salts combine with fats and make complexes of fats called micelles. The fats in the form of micelles can be absorbed easily.

3. Excretory function

Bile pigments are the major excretory products of the bile. The other substances excreted in bile are i) heavy metals like copper and iron ii) Some bacteria like typhoid bacteria iii) Some toxins iv) Cholesterol v) Lecithin vi) Alkaline phosphatase

4. Laxative action

Laxative is an agent which induces defecation. Bile salts act as laxatives by stimulating peristaltic movements of the intestine.

5. Antiseptic action

Bile inhibits the growth of certain bacteria in the lumen of intestine by its natural detergent action.

6. Maintenance of pH in gastrointestinal gland

As the bile is highly alkaline, it neutralizes acid chime which enters the intestine from stomach. Thus, an optimum pH is maintained for the action of digestive enzymes.

INTESTINAL JUICE

Intestinal glands

Small intestine is the part of GI tract extending between the pyloric sphincter of stomach and ileocaecal valve, which opens into large intestine. The mucous membrane of small intestine is covered by minute projections called villi.

The Crypts of Lieberkuhn or intestinal glands are simple tubular glands of intestine. These glands open into lumen of intestine between the villi. The intestinal glands are lined by columnar cells. The lining of each gland is continuous with epithelial lining of the villi.

In addition to intestinal glands, the first part of duodenum contains some mucus glands, which are called Brunner's glands secrete mucus and traces of enzymes.

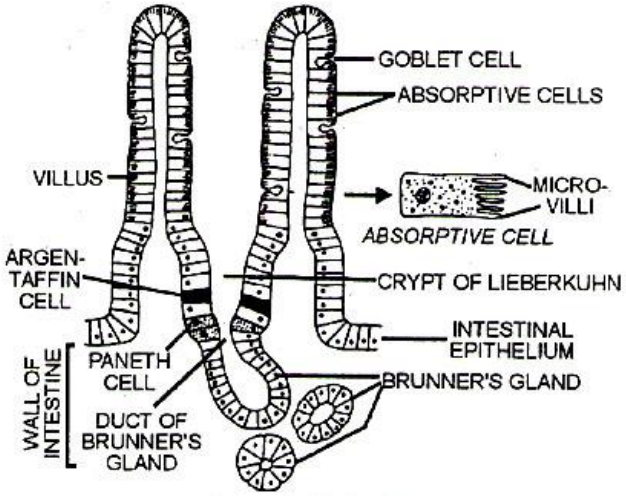


Fig 14 - Intestinal gland

PROPERTIES AND COMPOSITION OF INTESTINAL JUICE

Secretion from small intestine is called Succus entericus.

Properties

Volume: 1,800ml / day

Reaction: Alkaline

pH: 8.3

Composition of Succus entericus

The succus entericus contains water (99.5%) and solids (0.5%). Solids include organic and inorganic

substances. The bicarbonate concentration is slightly high in succus entericus.

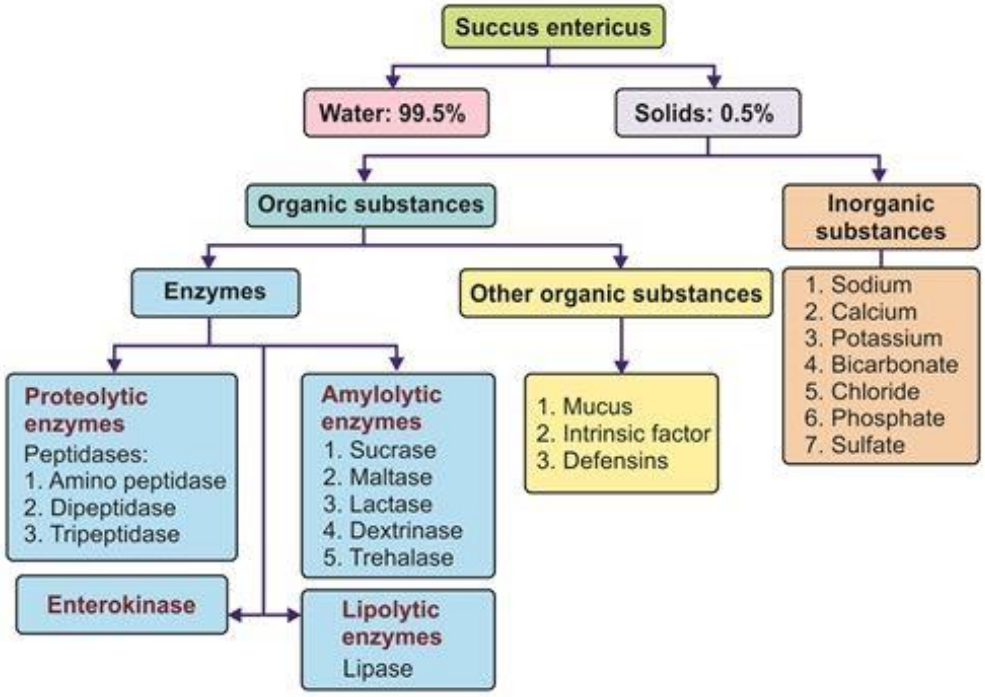


Fig 15 - Composition of Succus Entericus

Functions of Succus Entericus

1. Digestive function

The enzymes of succus entericus acts on the partially digested food and convert them into final digestive products.

2. Protective function

The mucus present in the succus entericus protects intestinal wall from the acid chyme, which enters the

intestine from stomach, thereby it prevents the intestinal ulcer.

3. Activator function

The enterokinase present in intestinal juice activates trypsinogen into trypsin. Trypsin which in turn activates other enzymes.

4. Hemopoietic function

The intrinsic factor of Castle, which is present in the intestine, plays an important role in erythropoiesis.

5. Hydrolytic process

Intestinal juice helps in all the enzymatic reactions of digestion.

DIGESTION AND ABSORPTION OF PROTEINS

Proteins

Adult human diet contains 25 to 40 grams of proteins. Children require much more proteins. The dietary proteins include albumins, globulins, nucleoproteins, caseinogen, collagen, gelatin, mucin elastin etc.

In the process of digestion proteins are split into amino acids. Nearly about 50 gms of protein is derived daily from desquamated cells and gastrointestinal secretions.

Place of protein digestion

Digestion of protein occurs in the stomach and intestine. It does not occur in the buccal cavity.

Glands involved in protein digestion

Protein digestion is helped by the following digestive glands

1. Pancreas
2. Gastric glands
3. Intestinal glands

Enzymes involved in protein digestion

The enzymes responsible for protein digestion are called proteases or peptidases or proteolytic enzymes.

The following are the proteases

1. Pepsin
2. Trypsin
3. Chymotrypsin
4. Carboxypeptidase
5. Aminopeptidase
6. Dipeptidase
7. Renin

STEPS IN PROTEIN DIGESTION

During digestion proteins are split into amino acids step by step. First of all proteins are split into proteoses. Proteoses are then split into peptones. Peptones are split into poly peptides. The poly peptides are split into dipeptides. Finally dipeptides are split into amino acids.

Proteins ----------→ Proteoses

Proteoses ----------→ Peptones

Peptonse ----------→ Poly peptides

Poly peptides ----------→ Dipeptides

Dipeptides ----------→ Amino acids

ACTION OF PEPSIN

Pepsin is a proteolytic enzyme and is secreted by the gastric glands.

It is secreted in an inactive form called pepsinogen. The hydrochloric acid activates this enzyme into pepsin.

Pepsin acts on native proteins and milk and convert them into proteoses, peptones and polypeptides.

Native protein----------→Proteoses + Peptones + Polypeptides

Calcium + Casein (milk) ----------→ Calcium paracasein (Curd) + Proteose

Calcium paracasein ----------→ Proteoses + Peptones + Polypeptides

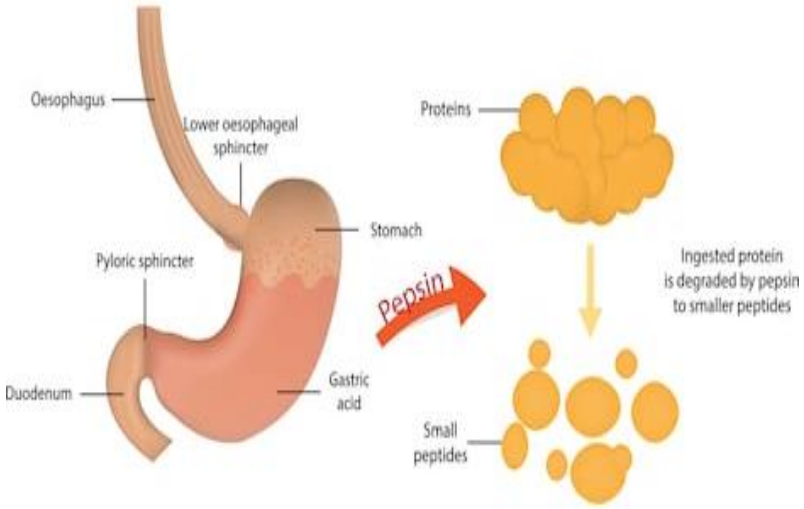


Fig 16 - Digestion of proteins by Pepsin

TRYPSIN

Trypsin is a single polypeptide with a molecular weight of 25,000. It contains 229 amino acids.

Trypsin is a proteolytic enzyme secreted by the pancreas.

It is secreted in an inactive form called trypsinogen

It is activated by another enzyme called enterokinase. Enterokinase is otherwise called enteropeptidase and it is

secreted by the brush bordered cells of duodenal mucus membrane.

Actions of trypsin

Trypsin is the powerful proteolytic enzyme. It converts protein, proteoses and peptones into polypeptides and dipeptides

Native protein ----------→ Proteoses + Peptones + Polypeptides

Proteose ----------→ Peptones

Peptone ----------→ Polypeptides

Polypeptides ----------→ Dipeptides

It accelerates blood clotting, it activates other enzymes of pancreatic juice such as chymotrypsinogen into chymotrypsin, procarboxypeptidases into carboxypeptidases, proelastase into elastase, procolipase into colipase.

Trypsin also activates collagenase, phospholipase A and phospholipase B.

CHYMOTRYPSIN

Chymotrypsin is a polypeptide with a molecular weight of 25,700 and 246 amino acids. It is secreted as inactive

chymotrypsinogen and activated into chymotrypsin by trypsin.

It is a proteolytic enzyme secreted by pancreas.

Action of Chymotrypsin

Digestion of proteins: Chymotrypsin is also an endopeptidase and it breaks the proteins into polypeptides

Digestion of milk: Chymotrypsin digests casein faster than trypsin. The combination of both enzymes causes more rapid digestion of milk.

Carboxypeptidase

The two carboxypeptidases are Carboxypeptidase A and Carboxypeptidase B. These are secreted as procarboxypeptidase A and procarboxypeptidase B. The inactive procarboxypeptidases are activated by trypsin.

Action of carboxypeptidase

Carboxypeptidases are exopeptidases and split the polypeptides and other proteins into amino acids.

Aminopeptidase

Aminopeptidase is a proteolytic enzyme secreted by pancreas. Its action is similar to that of carboxypeptidase. It acts on proteoses, peptones and polypeptides converting them into dipeptide and amino acids.

Dipeptidase

It is a pancreatic enzyme. It acts on dipeptides and splits them into amino acids

Digestion of peptides by Succus entericus

Succus entericus has exopeptidases enzymes Erepsin, which act at optimum pH 8 and temperature 40°C and convert the tripeptide and dipeptide into respective amino acids.

ABSORPTION

Absorption is a process by which the end products of digestion are transported from the lumen of alimentary canal to the blood stream through the intestinal wall.

PLACE OF ABSORPTION

Food is not at all absorbed in the buccal cavity. Stomach is also not a place for absorption. However simple substances which do not require digestion are absorbed in the stomach. They include water, alcohol, saline, glucose, easily diffusible drugs.

Small intestine is the main place for absorption. The anterior part of intestine is concerned with effective absorption. Large intestine absorbs water, saline, glucose, alcohol and certain drugs.

ABSORPTION OF PROTEINS

Protein absorption is mainly in the form of amino acids, although some forms of peptides and foreign proteins can also be absorbed as such. The foreign proteins bring about the formation of specific antibodies, these themselves acting as 'antigens'.

Pyridoxal is essential for the process of aminoacids absorption. The absorption of laevo forms of amino acids is generally quicker than their dextro forms.

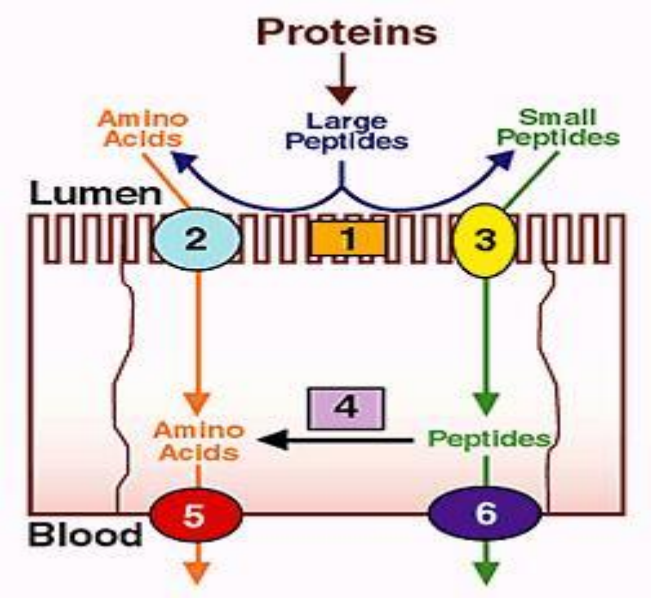


Fig 17 - Absorption of proteins

DIGESTION AND ABSORPTION OF CARBOHYDRATES

Carbohydrates

Carbohydrate is an important component of diet. Human diet contains 60 to 83% of carbohydrates. They provide the main bulk of the energy for the organism, hence are regarded as primary energy producers. The breakdown of complex carbohydrates into monosaccharide is called Carbohydrate digestion.

Carbohydrates as a food consist of

i) Starch and Cellulose (Polysaccharides) – of which the polysaccharide is not digested in alimentary canal of human beings and only acts as 'Rough age'. Glucose bonds of cellulose are linked with β glycosidic bonds which are resistant to digestion in man.

ii) Sucrose, lactose and maltose (disaccharides) which are split up into monosaccharides

iii) Glucose, fructose etc (monosaccharides) which need no digestion and are absorbed as such.

PLACE OF CARBOHYDRATE DIGESTION

The digestion of carbohydrate occurs in the buccal cavity, stomach and intestine.

GLANDS INVOLVED IN CARBOHYDRATE DIGESTION

Carbohydrate digestion is helped by the following glands i) Salivary glands ii) Pancreas iii) Gastric glands iv) Intestinal glands

ENZYMES INVOLVED IN CARBOHYDRATE DIGESTION

The breakdown of carbohydrates is brought about by a set of enzymes called 'Carbohydrases'. They are as follows

i) Amylase (Ptyalin)
ii) Maltase
iii) Lactase
iv) Sucrase
v) Amylopsin
vi) Cellulase

Amylase

Digestion of starch

Starch is digested by amylase enzyme of saliva and pancreatic juice. Salivary amylase acts only on boiled starch, whereas pancreatic amylase can act both on boiled and unboiled starch.

The main digestion of starch is brought about by pancreatic amylase. These amylases convert starch up to maltose stage.

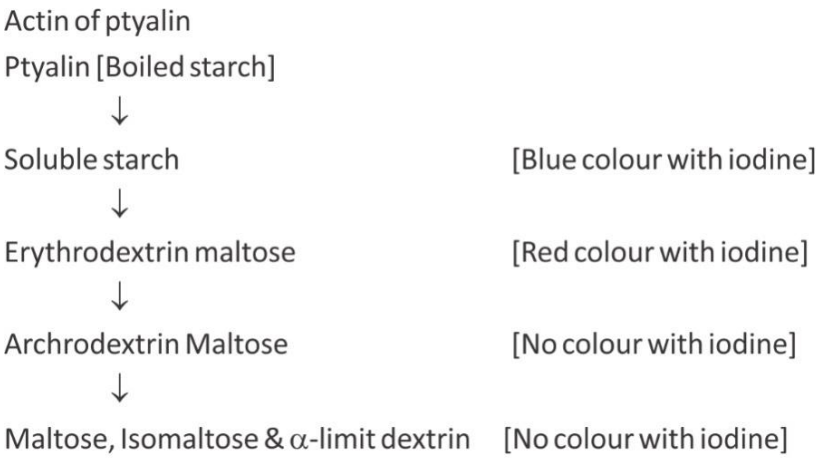


Fig 18 - Digestion of Starch by amylase

Salivary amylase (Ptyalin) is α amylase acting on interior of polysaccharide chain. Starch has straight chains of amylose linked by α 1- 4 glycosidic bonds or has branched chains of amylopectin with branch at points formed by α 1- 6 glycosidic bonds. Salivary amylase acts at optimum pH 6.5 and temperature 40° - 50°C.

Pancreatic amylase (amylopsin) has α amylase and β amylase (act on end of polysaccharide chain). It acts at optimum pH 6.7 – 7 and temperature 40° - 50°C. The mode of action is same as that of salivary amylase. Pancreatic amylase is absent in infants up to the age of 6 months.

Digestion of Disaccharides

There is no action of saliva on disaccharides, however there is presence of traces of maltase in saliva, which acts on maltose.

The gastric Hcl may hydrolyze sucrose (cane sugar) to some extent. Pancreatic juice also has traces of maltase which acts on maltose.

The disaccharides are mainly acted upon by enzymes of succus entericus after conversion of starch into maltose by amylases (mainly pancreatic).

The digestion of maltose, sucrose and lactose are as follows

Digestion of maltose

Maltose is digested by maltase enzyme.

Maltase is secreted by salivary glands and gastric glands

Maltase splits up maltose into two molecules of glucose

Maltose ----------→ Glucose + Glucose

Digestion of Sucrose

Sucrose is digested by sucrase enzyme.

Sucrase is secreted by gastric glands

Sucrase splits up sucrose into glucose and fructose

Sucrose ----------→ Glucose + Fructose

Digestion of lactose

Lactose is digested by lactase enzyme.

Lactase is secreted by gastric glands

Lactase splits up lactose into glucose and galactose

Lactose ----------→ Glucose + Galactose

Digestion of Cellulose

Cellulose is digested by cellulose. Man cannot produce cellulose. In herbivorous animals, the alimentary canal contains numerous bacteria and protozoans. These microorganisms absorb cellulose and convert it into glucose.

ABSORPTION OF CARBOHYDRATES

Carbohydrate absorption occurs in the form of monosaccharides by physical process of diffusion, filtration etc, but the active transportation is by process of phosphorylation which explains the increased rate of absorption not consistent with the involved physical factors only.

The phosphorylation brings about the combination of hexoses and phosphoric acid which are absorbed as such.

After absorption these undergo dephosphorylation, when phosphoric acid and hexoses are separated from each other

and the glucose then enter the blood stream via portal circulation.

The phosphorylation is controlled by adrenal cortex, and is also aided by Na+, B complex vitamins like thiamine, pantothenic acid and pyridoxine. The phosphorylation reaction is catalyzed by the enzyme phosphokinase.

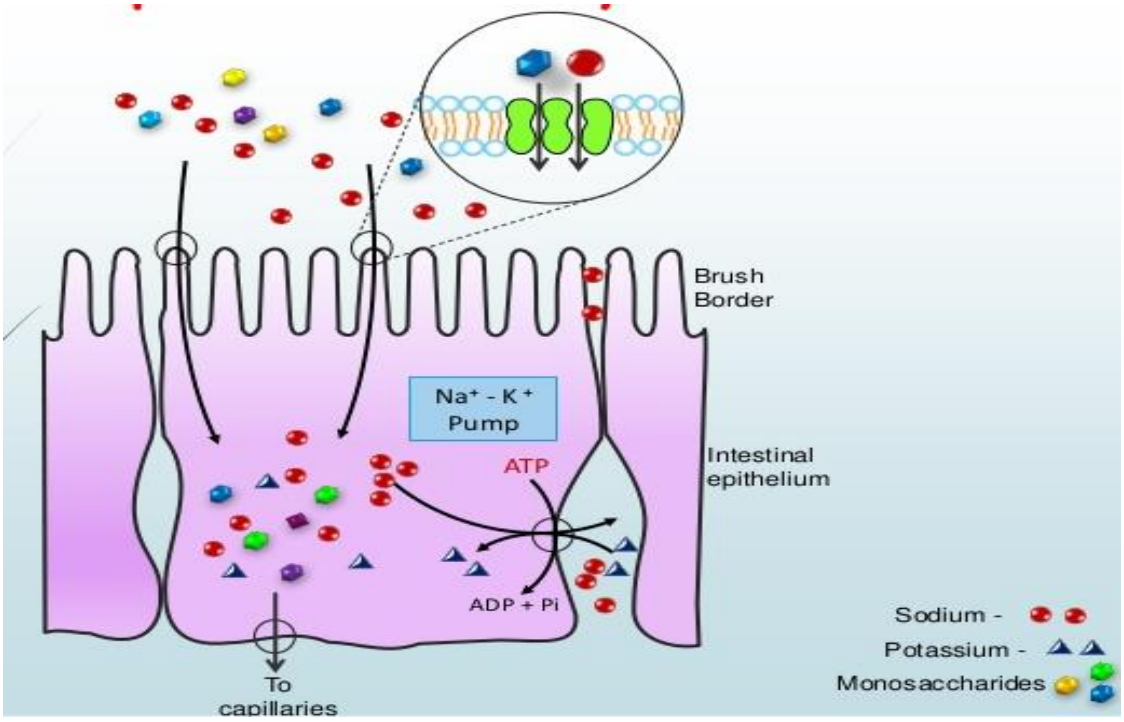


Fig 19 - Absorption of Carbohydrates

DIGESTION AND ABSORPTION OF LIPIDS

Lipids

Lipids are the second major source of energy for animals. The dietary lipids include neutral fats, phospholipids, cholesterides, free cholesterol, fatty acids and glycerol.

During digestion, the lipids are split into fatty acids and glycerol.

Lipids ----------→ Fatty acids + Glycerol

The conversion of neutral fats into glycerol and fatty acids occurs by process of hydrolysis.

PLACE OF LIPID DIGESTION

The digestion of lipid occurs in the stomach and intestine. It does not occur in the buccal cavity.

GLANDS INVOLVED IN LIPID DIGESTION

Lipid digestion is helped by the following glands

i) Gastric glands
ii) Liver
iii) Pancreas

ENZYMES INVOLVED IN LIPID DIGESTION

The breakdown of lipids is brought about by a set of enzymes called lipases. The following are the lipases.

i) Gastric lipase
ii) Pancreatic lipase
iii) Phospho lipase
iv) Phosphodiesterase
v) Phosphatase
vi) Cholesterol esterase

Emulsification

Emulsification is a process by which the insoluble lipids are converted into a soluble milky liquid containing drops of oil and fat.

It is the first step in the digestion of fat and it occurs in the stomach.

Emulsification is brought about by the bile secreted by the liver.

Only after emulsification, the proteases and lipases begin their digestive function on lipids.

Gastric lipase

Digestion of neutral fats

Neutral fats are acted by gastric lipase and are split into fatty acids and glycerol in a series of steps. In the stomach gastric lipase acts to a minor degree only on emulsified form of fats, as lipase activity is practically nil in acidic medium.

In the first step, the hydrolysis of neutral fats leads to the formation of one molecule of fatty acid and another molecule of diglyceride. The diglyceride is then split into one molecule of fatty acid and another molecule of monoglyceride. The monoglyceride is then hydrolysed into

one molecule of fatty acid and another molecule of glycerol.

Thus, each molecule of neutral fat produces three molecules of fatty acids and one molecule of glycerol.

Neutral fat ----------→ Diglyceride + Fatty acid

Diglyceride ----------→ Monoglyceride + fatty acid

Monoglyceride ----------→ Glycerol + Fatty acid

Pancreatic lipase

Main digestion of fats is however carried out by pancreatic lipase or Steapsin at optimum pH 8 and temperature of 40°C.

Steapsin is a fat splitting enzyme. Its activity is increased in the presence of a number of substances like Ca, soaps, bile acids, certain amino acids and peptides. It is a glyceride hydrolyzing enzyme. The end products of hydrolysis by this enzyme consist of diglycerides, monoglycerides and fatty acids.

Phospholipase

The pancreatic enzyme Phospholipase acts on lecithin and cephalin and removes one fatty acid. This leads to the

formation of substances called lysolecithin and lysocephalin, which are further hydrolysed and the second fatty acid is removed. This leads to the formation of glycerol, phosphoryl choline and other similar products.

Lecithin ----------→ Lysolecithin + Fatty acid

Cephalin----------→ Lysocephalin + Fatty acid

Phosphodiesterase

Glycerol is split off by phosphodiesterases

Phosphatases

Choline and Sphingosine are freed by the action of phosphatases

Cholesterol Esterase

Cholesterol is freed from Cholesterides by Cholesterol esterase

Intestinal lipase

Intestinal lipase acts, if any fat escapes the action of pancreatic lipase. Lipid digestion is completed in the intestine by the intestinal enzyme called intestinal lipase.

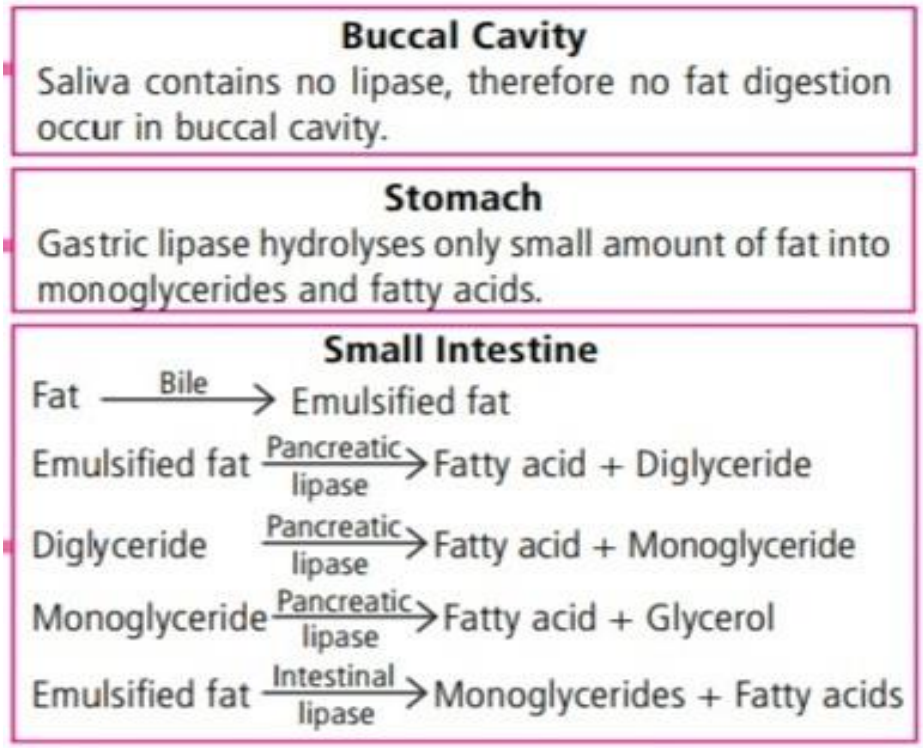


Fig 20 - Digestion of lipids

ABSORPTION OF LIPIDS

According to Frazer's theory (1956), the fats are emulsified and hydrolyzed by bile salts, so that chylomicrons are held either in oil phase or water phase. Those in oil phase are absorbed through lacteals in lymphatic system while those in water phase are absorbed either via lymphatics or portal circulation. The chylomicrons enter the epithelial cells through brush borders of villi by pinocytosis.

The long chain fatty acids resynthesize in epithelial cells with glycerol to form triglycerides and enter the

lymphatics, while the short chain fatty acids remain as such and enter the portal blood.

Fats are emulsified and hydrolyzed by bile salts to fatty acids and glycerol, which form a complex structure with bile salts, and are absorbed in epithelial cells. In the cells, there is breakdown of the complex structure, so that bile salts are released, while the fatty acids and glycerol form triglycerides by phosphorylation and pass on into lymphatic vessels and thence into blood.

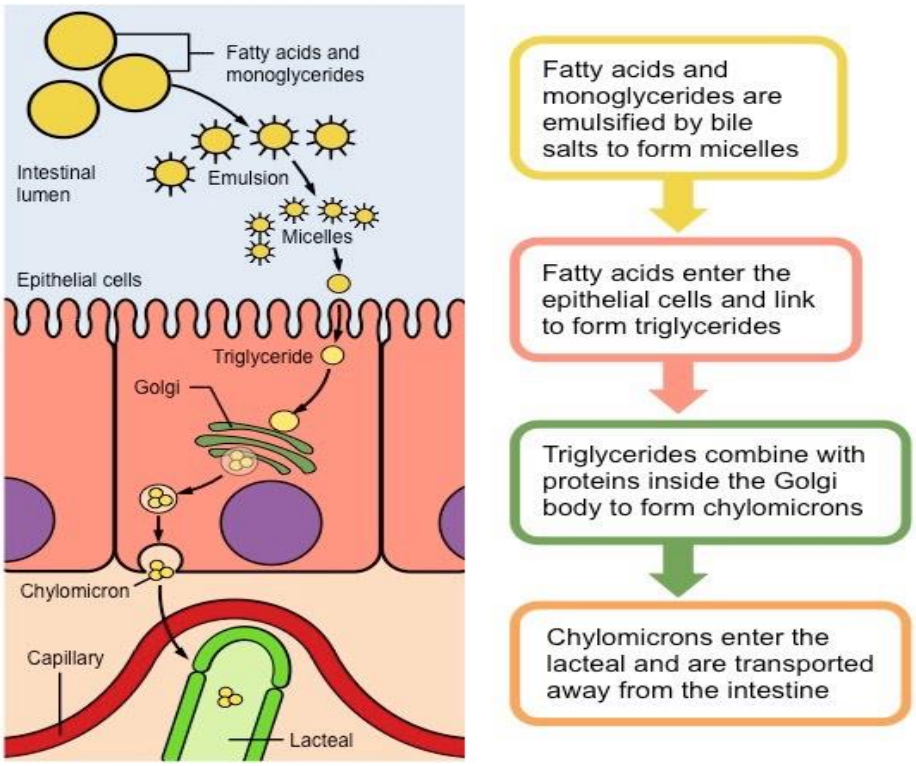


Fig 21 - Absorption of lipids

ROLE OF GASTROINTESTINAL HORMONES IN DIGESTION

The mucosa of gastrointestinal tract secretes a number of hormones which help in the process of digestion by regulating release of various digestive secretions.

Gastrointestinal hormones or gut hormones constitute a group of hormones secreted by enteroendocrine cells in the stomach, pancreas and small intestine that controls various functions of the digestive organs.

There are five main hormones that aid and regulate the digestive system in mammals. They are

i) Gastrin
ii) Secretin
iii) Cholecystokinin
iv) Gastric Inhibitory Peptide
v) Motilin

The release of these hormones is mainly regulated by the presence or absence of particular food in the lumen of the gastrointestinal tract. All the gut hormones are protein in nature and play a significant role in regulating the interconversions of nutrients to metabolic substances and their stored forms.

GASTRIN

Gastrin is a peptide hormone that stimulates the gastric glands to secrete gastric acid by the parietal cells of the stomach, pepsinogen (an inactive form of pepsin) and aids in gastric motility.

Its inactive form is called Preprogastrin, which is processed into fragments of polypeptide chains of various sizes.

It is produced by 'G' cells in the lining of stomach and upper small intestine. The secretion of gastrin is stimulated by food arriving in the stomach. It is inhibited by low pH.

In the Zollinger Ellison syndrome, gastrin is produced at excessive levels, often by a gastrinoma of the duodenum or the pancreas.

To investigate the hypergastrinemia condition (high blood gastrin levels), a "Pentagastrin" test can be performed.

Additionally, elevated gastrin levels may be present in chronic gastritis, resulting from Helicobacterpylori infection.

Biological action of gastrin

1. It stimulates the parietal cells of the stomach to secrete hydrochloric acid, parietal cell maturation, histamine secretion from ECL cells and fundal growth.
2. It causes chief cells to secrete pepsinogen, the zymogen (inactive) form of the digestive enzyme, Pepsin
3. It increases antral muscle mobility and promotes stomach contractions.
4. It plays a role in the relaxation of the ileoceacal valve
5. It induces pancreatic secretions and gall bladder emptying.
6. It contributes to the gastrocolic reflex.

SECRETIN

Secretin is a linear polypeptide of 27 amino acid residues, having a molecular weight of 3200. It is produced by intestinal mucosa.

In 1902, Bayliss and Starling first demonstrated that the excitatory effect of duodenal stimulation on pancreatic secretion was due to blood borne factor. The factor was then identified as secretin.

Biological function of secretin

1. Secretin is in the duodenum and signals the secretion of sodium bicarbonate in the pancreas and it stimulates the

secretion of bile in the liver. This hormone responds to the acidity of the chyme.

2. Secretin regulates water homeostasis throughout the body and influences the environment of the duodenum by regulating secretions in the stomach, pancreas and liver.
3. Secretin mechanism is an automatic process to prevent excess acid in the upper part of the small intestine.
4. Secretin regulates the pH of the duodenum.
5. It also stimulates the bile production by the liver, the bile emulsifies dietary fats in the duodenum.
6. Secretin is used in a diagnostic test for pancreatic function.

CHOLECYSTOKININ (CCK)

Cholecystokinin has been found to be a polypeptide containing 33 amino acids. Its hormonal action resides in the octapeptide of the C-terminal end.

The existence of CCK was first suggested in 1905 by the British Physiologist, Joy Simcha Cohen.

Cholecystokinin is officially called Pancreozymin, and is synthesized and secreted by enteroendocrine cells in the duodenum.

This hormone is secreted in response to the fat in chyme. The release of CCK is inhibited by Somatostatin and pancreatic peptide.

Biological function of CCK

1. CCK plays important roles both as a neuropeptide in the central nervous system and as a peptide hormone in the gut.
2. It participates in a number of processes such as digestion, satiety and anxiety. It stimulates the digestion of fat and protein.
3. It improves digestion by slowing down the emptying of food from the stomach and stimulating the production of bile in the liver as well as its release from the gall bladder.
4. Increased blood levels of CCK can be found 15 minutes after a meal has begun and levels remain raised for 3 hours afterwards.
5. Along with secretin it promotes the contraction of pyloric sphincter and prevents the reflex of duodenum into the stomach.

GASTRIC INHIBITORY PEPTIDE (GIP)

Gastric Inhibitory Peptide (GIP) is in the duodenum and decreases the stomach churning in order to slow the

emptying of the stomach. It is a member of the secretin family of hormones.

Like secretin, it is secreted from mucosal epithelial cells in the first part of the small intestine.

GIP also enhances the release of insulin by stimulating the beta cells in pancreatic islets and in response to infusions of glucose. Hence it is also referred to as Glucose Dependent Insulinotropic Peptide

MOTILIN

Motilin is in the duodenum and increases the migrating myoelectric complex component of gastrointestinal motility and stimulates the production of pepsin.

Motilin stimulates the contractile activity in the stomach and small intestine. It is a regulatory peptide of the gastrointestinal tract that stimulates enzyme secretions by the stomach and pancreas and induces strong phasic contractions of the stomach.

It participates in controlling the pattern of smooth muscle contractions in the upper gastrointestinal tract.

OTHER GASTROINTESTINAL HORMONES

1. ENTEROGASTRONE

It is produced in the small intestine in the presence of fatty substances in the duodenum but acts on the stomach by inhibiting the movements and Hcl secretion.

2. GHRELIN

It is secreted by stomach with secretion decreased by feeding and increased by fasting.

3. NEUROTENSIN

It is a polypeptide hormone containing 13 amino acid residues, it inhibits gastrointestinal motility and increases ileal blood flow.

4. VASOACTIVE INTESTINAL PEPTIDE (VIP)

It promotes the intestinal secretion of electrolytes and water. It also relaxes the intestinal smooth muscle.

5. SUBSTANCE P

It is found in endocrine and nerve cells in the gastrointestinal tract and may enter the circulation. It increases intestinal motility.

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CHAPTER-II

RESPIRATION AND CIRCULATION

Physiology of respiration in Man. Respiratory Pigments, nervous and chemical control of respiration, BMR. Circulation - types of hearts - physiology of cardiac muscle - heart beat and its regulation - blood coagulation and theories.

Mrs. M. ANURADHA, M.Sc., M.Phil

Assistant Professor,

Department of Zoology,

Auxilium College (Autonomous),

Gandhi Nagar, Vellore District, Tamil Nadu.

E.mail: anu.m1477@gmail.com

RESPIRATION:

Respiration is an essential physiological activity of all living organisms. It is defined as the gaseous exchange between the organism and the environment. By respiration energy is released through oxidation of food in our body. Hence it can be described as the process of biological oxidation where O, is utilized andCO, is given out.

PHYSIOLOGY OF RESPIRATION

Respiration is a complex process by which the organism meets its oxygen need and eliminates carbon dioxide from the body. In higher animals and man, the process of respiration involves following processes:

1) EXTERNAL RESPIRATION:

It is also called as breathing, which includes two phases, namely inspiration and expiration. It can also be defined as the uptake of O2 and excretion of CO2 in the lungs.

2) INTERNAL RESPIRATION:

It means the O2 and CO2 exchange between the cells and capillary blood and active cells of the organism. Since it takes place at cellular level it is called as cellular respiration.

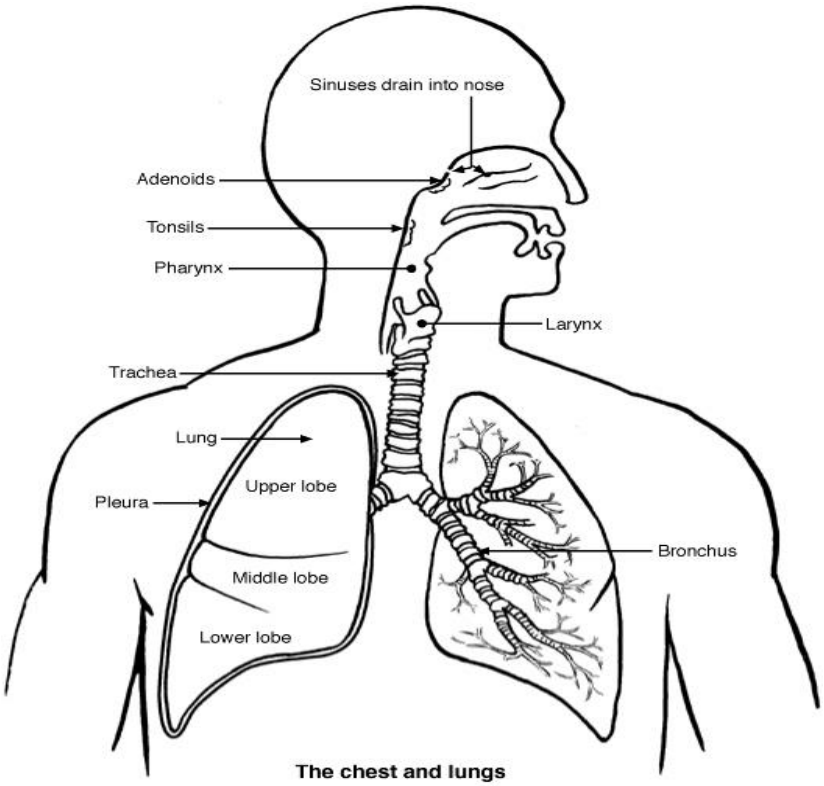
RESPIRATORY ORGAN OF MAN:

The respiratory organ of man is lungs. Man has two lungs. They are spongy in nature. They are located in the thoracic cavity. The lungs are roughly conical shaped with the apex at the top. The right lung has 3 lobes;superior, middle and inferior. The left lung has 2 lobes; superior and inferior lobes. Left lungs is slightly smaller than the right - this is due to the presence of the heart. The lungs are connected to the external nostrils through respiratory passage. Each lung is surrounded by a pleural cavity and are covered by a protective membrane called as the pleura.

They are separated from the abdominal cavity by the muscular diaphragm. The lungs rests on the dome of the diaphragm, and has a concave shape. This concavity is deeper on the right-side lung because of the higher position of the right dome overlying the liver. The respiratory passage consists of External nostrils, Nasal cavity, internal nostrils, Pharynx, Larynx, Trachea, Bronchus, Bronchioles. The trachea is the windpipe located inside the neck.

The human trachea or the windpipe divides into two main branches called main stem bronchi. The bronchi enter

the lungs and are called primary bronchi. The primary bronchi divide further to form secondary bronchi. The secondary bronchi divide into tertiary bronchi. The tertiary bronchi divide into terminal bronchi. The terminal bronchi divide into bronchioles. The bronchioles lead into alveolar ducts. The alveolar duct opens into a wide space called vestibule. The vestibule receives many infundibula. Each infundibulum has a bunch of alveolus or air sacs. The alveolus consists of a single layer of epithelial cells. The lung receives deoxygenated blood through pulmonary artery. The oxygenated blood is carried away from the lungs by pulmonary vein.



The chest and lungs

From larynx down to the terminal bronchioles, cartilages are present in the wall which keep the lumen patent.

1. Air is equilibrated with the body temperature (air at 6°C when inhaled, is warmed up to 30°C and expired air is always below 37°C) in the air passage.

2. Dust particles, suspended in air, are retained by:

(i) The hairs around the nostrils;

(ii) They are obstructed by the zig-zag passage, produced by the turbinate (nasal conchae) bones;

(iii) They are wafted up by the cilia of the epithelial lining of the respiratory passage. Sizes of the particles greater than 4 unit micron cannot enter alveoli of the lungs by the above mechanisms. Smoke particles whose diameters are less than 4 unit micron, can enter the lungs;

(iv) Larynx is the watch dog of the respiratory passage. Any particle that gains access to it, causes irritation and is coughed out;

v) Sneezing along with coughing also helps clearing the respiratory passage of any irritating material;

(vi) Mucous secretion also prevents entry of foreign particles to lungs, by sticking to them.

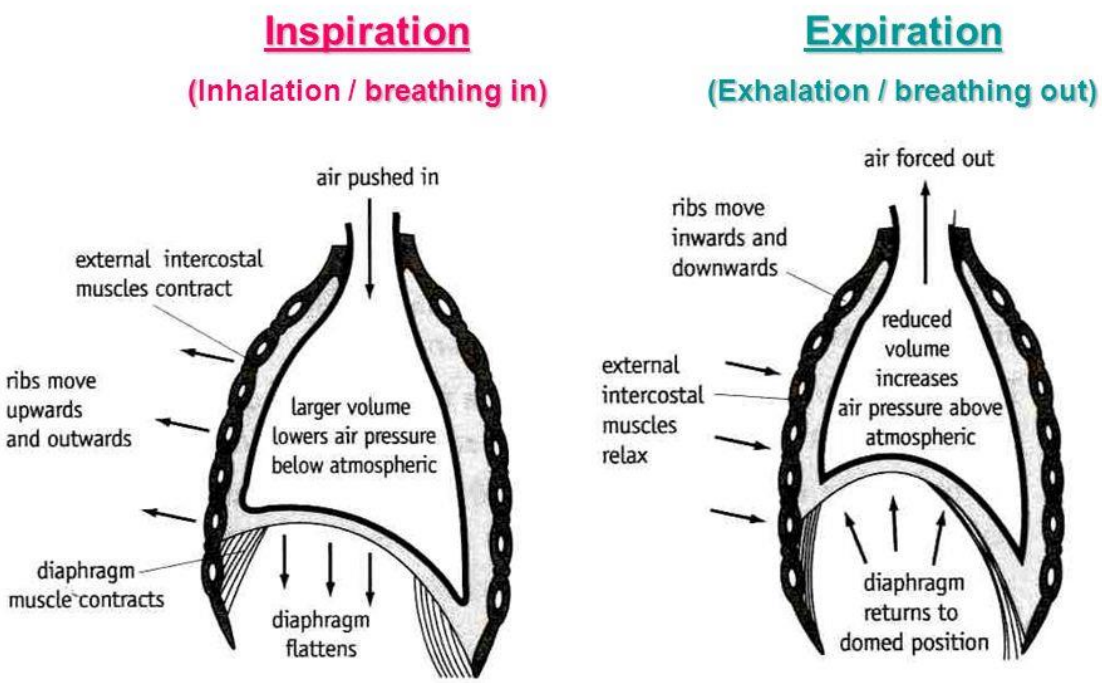
3. The organ of smell being situated within the nasal cavity, smell sensation enables one to judge the nature of the air, bad or good, and he is able to discard offensive or pungent air;

4. The air is also moistened by the vascular nasal mucosa, as it passes along it.

MECHANICS OF RESPIRATION:

The events at respiration are: (1) to force air into lungs, (2) to distribute air into 500-750 million alveoli of lungs and (3) to effect diffusion of gases between blood and the alveolar air and (4) finally to expel the air out.

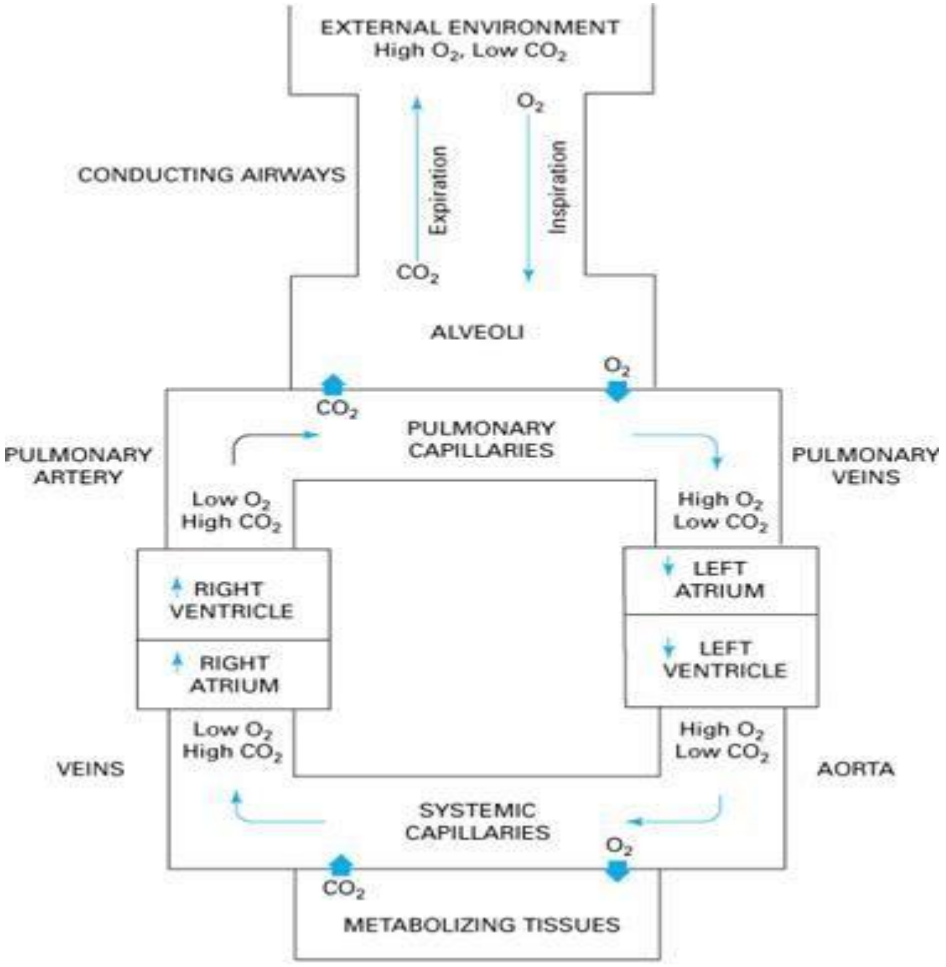
The mechanism for the above purposes, consists of rhythmic expansion of chest wall or inspiration, followed by retraction of the same or expiration, in which air is sucked in and expelled out of it. The processes of inspiration and expiration is mediated by nervous and chemical factors.



Thus, the movement of respiration is seen to be a cyclic movement, consisting of inspiratory and expiratory phases. Normally, one follows the other. The inspiratory phase is shorter and lasts about 1 second in resting condition, whereas the expiratory phase is longer and lasts about 3 seconds. The inspiratory phase is active and is brought about by active contraction of inspiratory muscles; the expiratory phase is mostly passive, and is brought about by elastic recoil of the lungs and the chest wall, and partly active, brought about by contraction of the expiratory muscles.

When the thoracic cavity starts enlarging during inspiratory phase, the already existing intrapleural negative

pressure (-5 mm.Hg.) is further increased (-10 mm.Hg.) and at the same time the intrapulmonary pressure falls by about 2 mm.Hg., below atmospheric pressure and due to this pressure gradient, the lung follows the expanded chest wall and air rushes into the lung. Expansion is aided by the reduced alveolar surface tension due to the presence of a chemical compound, the surfactant, within the alveoli and by the hydraulic force exerted by the fluid smear that keeps the visceral and parietal pleura in contact with each other.



GAS EXCHANGE BETWEEN THE TISSUES, LUNGS AND THE ENVIRONMENT.

At the end of inspiration, the intrapulmonary pressure is 3 mm.Hg. more than the atmospheric pressure and the intrapleural negative pressure is reduced due to relaxation of inspiratory muscles, elastic recoil of lung and chest wall, and consequently, air is expelled out of the lungs through air passage.

Interchange of O_2, and CO_2 is of two types, namely pulmonary respiration and tissue respiration. In pulmonary respiration, interchange occurs in the lungs. It is also called external respiration. The air is taken in by inspiration through the external nostrils. It passes through the nasal cavity, internal nostrils, pharynx, larynx, trachea, bronchi and terminal bornchi. All these are the non-respiratory parts and they convey the air into the air sacs.

The exchange of gases takes place in the alveolar (air sacs). The alveolus is filled with air. The thin wall of the air sac is in close contact with capillary. Only one layer of membrane separates the oxygen from the blood. Oxygen passes across this membrane and is taken up by the haemoglobin of blood. This oxygen containing blood

leaves the lungs, reaches the heart and then goes to the various tissues to supply oxygen. The blood leaving the lungs is at an oxygen pressure of 100 mm Hg and 95% haemoglobin is saturated with O. This blood contains 20 ml of O_2 per 100 ml of blood. When O_2 passes into the blood from the alveolus, CO_2 passes from the blood into the alveolus. This air containing CO_2 goes out of lungs during expiration.

The volume of air present in the non-respiratory tubes is called anatomical dead space. The volume of air present in non-functional alveolus is called physiological dead space. The amount of air remaining inside lungs during expiration is called residual volume. In tissue respiration, the interchange of gases occurs in the tissue. It is also called internal respiration. The cells take up O_2 from the haemoglobin and the blood receives CO_2 from the cells.

TIDAL VOLUME AND VITAL CAPACITY:

The volume of air inspired and expired during normal breathing is called tidal volume. The maximum volume of air which can be ventilated during forced breathing is called the vital capacity of the lungs.

TOTAL LUNG CAPACITY AND DEAD SPACE:

The total lung capacity of human lungs is about 5 to 6 litres. Although 500ml of fresh air is breathed during each inspiration, only part of this air reaches the alveoli. The rest of the air fills the nasal cavity, trachea, bronchioles, etc. The air contained in these tubes, which is about 150 ml, is called dead space.

INCREASE IN RATES OF RESPIRATION:

The rate of respiration is usually proportional to the level of metabolism and is increased in nervous excitement, muscular exercise, fever and defective aeration of blood.

DECREASE IN RATE OF RESPIRATION:

The rate may be decreased in opium, barbiturate poisoning, narcotic poisoning, and pneumonia.

RESPIRATORY PIGMENTS

Respiratory pigments are coloured substances present in blood transporting O_2 and C O_2.

SALIENT FEATURES OF RESPIRATORY PIGMENTS:

- They are coloured pigments.
- They have special affinity for respiratory gases.

- They are distributed either in the blood or in the body fluids.
- They are the coloured proteins (chromoproteins) which contain a metallic ion.
- They play an important role in the transport of O_2 and CO_2. The following are the important respiratory pigments that are commonly within animals:

1. Haemoglobin
2. Haemocyanin
3. Haemoerythrin
4. Chlorocruorin
5. Pinnaglobin
6. Vanadium
7. Echinochrome
8. Molpadin.

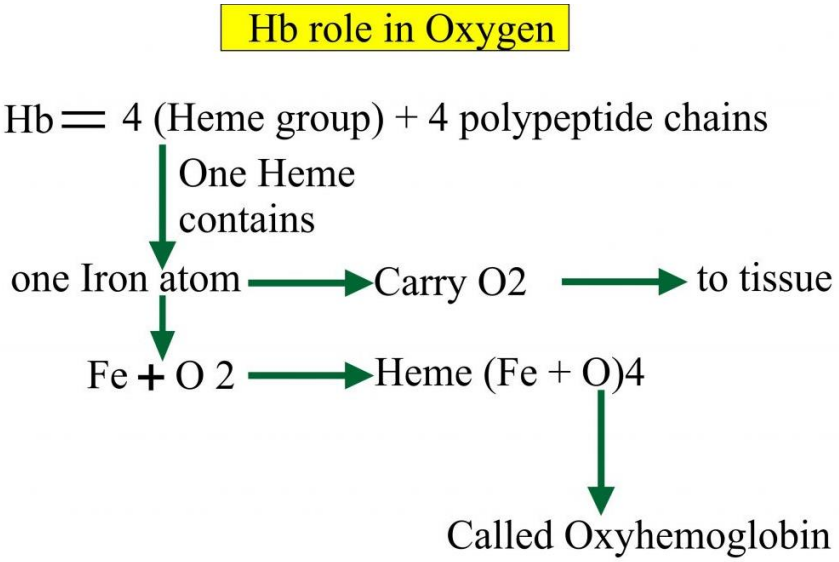
1. HAEMOGLOBIN:

- Haemoglobin is a red coloured respiratory pigment present in the blood.
- Haemoglobin occurs in all vertebrates, a few holothurians, several crustaceans, chironomus insects, Planorbis, annelids, parasitic nematodes, flatworms, Protozoa and also in the root nodules of some leguminous plants.

- It is seen in the red blood corpuscles of all vertebrates.
- The haemoglobin is also found in the muscles of birds and mammals. The haemoglobin present in the muscles is called myoglobin and it helps to store oxygen temporarily.
- Molecular weight of a haemoglobin is 68,000 daltons.
- Haemoglobin is a chromoprotein (conjugated protein)
- It is composed of two components, namely a protein component called globin and a non-protein component (prosthetic group) called haem.
- Globin is formed of four polypeptide chains. Of the four polypeptide chains, two are identical and are called alpha chains. An alpha chain is formed of 141 amino acids. The other two identical chains, are called beta chains. Each beta chain is formed of 146 amino acids.
- The haem is a non-protein and it is formed of iron and porphyrin.
- The porphyrin is the pigment and it gives red colour to haemoglobin.
- There are four haem molecules in one haemoglobin.
- Haemoglobin combines with oxygen to form oxyhaemoglobin. This com bination is loose. At low oxygen pressure, it leaves oxygen forming reduced

haemoglobin. One haemoglobin molecule can bind with 4 molecules of O_2.

- ❖ When haemoglobin is treated with hydrochloric acid, it forms brown coloured pigment called acid haematin.
- ❖ When haemoglobin is treated with glacial acetic acid, it forms haemin crystals.
- ❖ Haemoglobin transports O_2 from lungs to cells and C O_2 from cells to lungs.



2. HAEMOCYANIN:

- ❖ It is a blue coloured pigment.
- ❖ In 1934 Redfield did lot of work on this pigment.
- ❖ It is formed of copper and protein.
- ❖ The molecule of haemocyanin consists of one copper atom and a peptide chain of about 200 amino acids.

- Its molecular weight differs in different animal groups. For example, for Helix it is 6650000 and for Palinurus it is 4,47,000daltons.
- Like all proteins, haemocyanin absorbs ultra-violet rays.
- It is an oxygen transporting metalloproteins in the hemolymph of few invertebrates.
- Haemocyanin occurs in the blood plasma of Arthropods such as, Limulus and Daphnia and molluscs such as, Sepia, Octopus and Helix.

3. HEMERYTHRIN:

- It is a reddish-violet coloured pigment.
- It is formed of iron and protein. The iron is directly attached to the protein and there is no porphyrin.
- The molecular weight varied from 66,000 to 120,000 daltons.
- It occurs in the corpuscles of Sipunculus and the plasma of other organisms.
- It is present in the brachiopod Lingula, sipunculids, priapulids and the polychaeteMagelona.
- When compared with other respiratory pigments, it is less efficient carrying capacity.

4. CHLOROCRUORIN:

- It is a green coloured pigment.
- Milne Edwards discovered in Annelids.
- It is an oxygen-binding hemeprotein.
- It is closely allied to haemoglobin and cytochromes. 5. It occurs in the plasma.
- It functions only at high oxygen tension.
- Its distribution is restricted to polychaete Annelids. Eg. Sabella, Serpula.

5. PINNAGLOBIN:

- It is a brown coloured pigment.
- It occurs in the body fluid of Pinna.
- It is a manganese containing blood pigment.

6. VANADIUM:

- It is present in the blood cells (Vanadocytes) of Ascidians.
- It also occurs in the plasma of several other organisms.

7. ECHINOCHROME:

- It is a red coloured pigment.
- It is an iron containing pigment.
- It occurs in the coelomic fluid of sea urchin.

8. MOLPADIN:

- It occurs in the holothurian called Molpadia.

FUNCTIONS OF RESPIRATORY PIGMENTS:

The following are the most important functions of respiratory pigments:

- They are the oxygen carriers. In the absence of these pigments, blood could carry only lesser amount of oxygen.
- All the pigments have great affinity towards the respiratory gases. At high partial pressure they can combine with these gases and at low partial pressure they can dissociate.
- The respiratory pigments show reversibility in their action.
- They also function as buffers in the transport of CO_2
- The proteins of respiratory pigments help to maintain colloid and osmotic pressure of blood.

CONTROL OF RESPIRATION

Respiration is an automatic and rhythmic reflex process. Like the heartbeat, breathing must occur in a continuous, cyclic pattern to sustain life processes. Inspiratory muscles must rhythmically contract and relax to alternately fill the lungs with air and empty them. This activity is accomplished automatically, without conscious effort.

The normal rate of respiration in an adult is 14 to 18 per minute. The rate is controlled according to the

requirement of the body. Voluntary control of respiration (voluntary apnea) is possible for a short period of about 40 seconds. The pattern of respiration is regulated by two mechanism, namely;

1. Nervous control
2. Chemical control

1. NERVOUS CONTROL:

The respiratory muscles, being skeletal muscles, contract only when stimulated by their nerve supply. The rhythmic pattern breathing is established by cyclic neural activity to the respiratory muscles. In other words, the pacemaker activity that establishes breathing rhythm resides in the respiratory control centres in the brain, not in the lungs or respiratory muscles themselves. The nerve supply to the respiratory system is absolutely essential in maintaining breathing and in reflexly adjusting the level of ventilation to match changing needs for O_2 uptake and CO_2 removal. Respiratory activity is controlled by a special area of the brain called respiratory centre. There are four centres responsible for the regulation of respiration. They are;

In the medulla: 1.Inspiratory centre 2.Expiratory centre

In the pons: 3.Pneumotaxic centre 4.Apneustic centre

THE INSPIRATORY CENTRE:

It is located in the medulla oblongata and composed of group of neurons. It sends impulses to the inspiratory muscles resulting in inspiration. The inspiratory centre is in constant state of excitability.

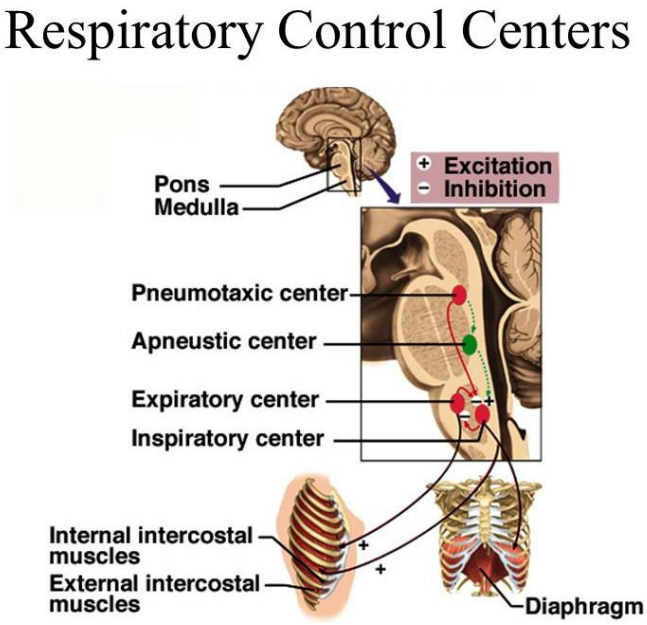
THE EXPIRATORY CENTRE:

It is also situated in the medulla oblongata but anterior to the inspiratory centre. It sends impulses to expiratory muscles resulting in expiration. Expiration results from the inhibition of inspiration. The expiratory centre is stimulated by pneumotaxic centre.

THE PNEUMOTAXIC CENTRE:

It is located in the pons of brain. Stimulation of this centre increases the respiratory rate. The expiratory centre is connected to vagus nerve. The vagus nerves innervate lungs. The lungs contain receptors called stretch receptors. During inspiration, the stretch receptors are stimulated and send impulses to the expiratory centre through the vagus

nerve. Expiratory centre then sends inhibitory impulses to the inspiratory centre to stop inspiration. This is called Heringbreuer reflex.



THE APNEUSTIC CENTRE:

It is situated in the pons of the brain. It provides the signal for the normal termination of inspiration. So this centre is called inspiratory cut off switch. Stimulation of this centre causes deep inspiration.

NERVES USED IN RESPIRATION:

There are several major nerves involved in the muscular functions ofrespiration. Three important respiratory nerves which direct the muscles to move air into and out of the lungs are:

THE PHRENIC NERVE:

This nerve originates from spinal cord. It provides exclusive motor control and stimulates the activity of the diaphragm. It is composed of two nerves, the right and left phrenic nerve, which pass through the right and left side of the heart respectively. They are autonomic nerves with mixed motor or sensory function.

THE VAGUS NERVE:

Innervates the diaphragm as well as movements in the larynx and pharynx. It provides deep breaths, modulates airway tone, perfusion and secretion. It is a major autonomic nerve.

THE POSTERIOR THORACIC NERVES:

These nerves originate from the spinal cord andstimulate the intercostal muscles located around the pleura. They are a part of larger group of intercostal nerves that stimulate regions across the thorax and abdomen. They are somatic nerves that control motor and sensory signals.

These three types of nerves continue the signal of the ascending respiratory pathway from the spinal cord to stimulate the muscles that perform the movements needed for respiration.

REFLEXOGENIC REGULATION:

Besides the generation of continuous activities of respiratory centres, respiration is profoundly modified by the afferent impulses from various sources. Few such protective reflexes are;

(a) COUGH REFLEX:

It produces a strong expiratory effort, when foreign materials enter into the lower part of respiratory tract.

(b) AN UPPER RESPIRATORY REFLEX:

It appears, when irritant materials enter into upper part of the respiratory passage.

(c) SUBMERSION REFLEX:

When water tends to enter into the upper respiratory tract, apnoea is produced and is called the submersion reflex

(d) SWALLOWING REFLEX:

It occurs indicating closure of the glottis and temporary cessation of inspiration as a result of swallowing.

(e) SNEEZING REFLEX:

Irritation of the nasal mucosa produces strong expiratory effort.

(f)YAWNING:

Yawning produces a deep inspiratory effort. The cause of yawning is considered to be due to inadequate oxygenation of blood, due to unequal ventilation of the alveoli of the lungs. The deep inspiratory effort in yawning flushes and ventilates the lungs and squeezes stagnant blood out of the pulmonary vessels.

(g) HICCOUGH:

Hiccough is manifested by a characteristic sound, as a result of the vibrations of the vocal cords due to the sudden and rapid indrawing of air into the lungs, caused by spasmodic contraction of diaphragm. Inhalation of 5% carbon dioxide usually stops it.

(h)MUSCULAR EXERCISE:

Hyperpnoea during exercise results from stimulation of respiratory centres, due to impulses originating in the muscles which are stimulated, as a result of local physicochemical changes, of pO2(partial pressure of oxygen), pCO2(partial pressure of carbon dioxide) and pH.

(i)PAIN:

Pain produces increased rate of respiration and may be due to the stimulation of the respiratory centre, as a generalized excitatory process.

(j)TEMPERATURE:

Rise in body temperature also increases the rate and depth of respiration by stimulating medullary centres.

2. CHEMICAL CONTROL:

The magnitude of ventilation is adjusted in response to three chemical factors: pO_2, pCO_2, H^{+}. No matter how much O_2 is extracted from the blood or how much CO_2 is added to it at the tissue level the pO_2, and pCO_2, of the systemic arterial blood leaving the lungs are held remarkably constant, indicating that arterial blood-gas content is precisely regulated. Arterial blood gases are maintained within the normal rangeby varying the magnitude of ventilation (rate and depth of breathing) to match the body's needs for O_2 uptake and CO_2 removal. If more O_2 is extracted from the alveoli and more CO_2 is dropped off by the blood because the tissues are metabolizing more actively, ventilation increases

correspondingly to bring in fresher O_2 andblow off more CO_2.

The medullary respiratory centre receives inputs that provide information about the body's needs for gas exchange. It responds by sending appropriate signals to the motor neurons supplying the respiratory muscles, to adjust the rate and depth of ventilation to meet those needs. CO_2, O_2 acidity, etc. influence the respiratory centre. The inspiratory centre is sensitive to CO_2 concentration. Excess CO_2 increases the rate of respiration. Decrease in CO_2 decreases the rate of respiration. Decreased level of oxygen in the blood will result in increased rate of respiration. The carotid body present in the common carotid is sensitive to the oxygen level of the blood. When oxygen level falls, the carotid body sends impulses to the inspiratory centre. This results in increased rate of respiration. When pH is lowered, the rate of respiration is increased. When pH is lowered, the rate of respiration in increased. When pH is increased, the rate of respiration is lowered. Low pH is associated with increased CO_2 and high pH is associated with decreased CO_2.

BMR

Basal Metabolic Rate(BMR) can be defined as the amount of heat produced by an individual who is in perfect physical mental and emotional rest and is in awaking state.

CONDITIONS FOR MEASURING BMR:

- It is measured at a comfortable temperature and pressure and after a light meal with a minimum amount of protein taken, 12 hours before, i.e., taken in the previous evening.
- The subject should not undertake any undue exercise in the previous 24 hours.
- Person should take at least half an hour rest in a bed before actual measurement of heat production is undertaken.
- The person should be at mental rest to minimize skeletal tone to prevent a rise in epinephrine (stress hormone) that increases metabolic rate.
- It is usually expressed in calories per square metre of body surface per hour. The standard value is 40 cal./hour/square metre of body surface for healthy adult male and 37 calories/hour/square metre of body surface for adult females, between 25-50 years age. (It is lower by 15% and 17% in case of Indian females and males respectively.)

Metabolic rate = energy expenditure/unit time.

The energy turnover during basal conditions sub serves the following purposes:

- ❖ Automatic muscle movements of heart, respiratory muscles and muscles of the digestive system.
- ❖ Generation and propagation of nerve impulse.
- ❖ Maintenance of body temperature.
- ❖ Formation of tissue proteins, making good the inevitable loss due to wear and tear and formation of various secretions, hormones and other complex metabolites.
- ❖ Maintenance of a constant internal environment. In terms of heat equivalent, it amounts to approximately 500 calories for a 8-hour period of rest in bed or sleep.

METHODS OF MEASURING THE BASAL METABOLIC RATE:

The rate of heat production in BMR determination can be measured directly or indirectly. With direct calorimetry, the person sits in an insulated chamber with water circulating through the walls. The difference in the temperature of the water entering and leaving the chamber reflects the amount of heat liberated by the person. Even though this method provides a direct measurement of heat production, it is not practical, because a calorimeter

chamber is costly and takes up a lot of space. Therefore, a more practical method of indirectly determining the rate of heat production was developed for widespread use. With indirect calorimetry, only the person's O_2 uptake per unit of time is measured, which is a simple task using minimal equipment. The BM is determined by a Benedict-Roth apparatus in indirect method, where the amount of O_2 consumed by a person per unit time. The O_2 consumed is converted into calories and measured.

FACTORS INFLUENCING BMR: A. PHYSIOLOGICAL:

1. SURFACE AREA:

BMR is proportional to the surface area of the body. So, a tall and lean man has greater BMR than a short, stout individual, because the former has greater surface area than the latter.

2.**AGE:**

Heat production is maximum in younger age group and minimum in older age group. New born babies have lower BMR than infants, and premature babies have lower BMR than babies born at full term.

3. SEX:

Females have lower rate of heat production due to lesser surface area.

4. RACE AND CLIMATE:

The difference of BMR between Eskimos in the arctic region and the people in the tropics could not be tenable, when seasonal fluctuation is taken into account.

5. HABITS:

Habituation to heavy muscular exercise as in athletes and manual labourers, leads to increased heat production, compared with the sedentary worker.

6. PREGNANCY:

It does not affect BMR as the increased BMR found in the last trimester, is due to the additional heat production by the foetus. The BMR of the expectant mother at term is equal to BMR of the mother after delivery, plus the BMR of the foetus.

7. DIET:

Any article of food is effective in raising the BMR. A mixed diet definitely raises the BMR, but a vegetarian has 11% lower BMR than persons having a mixed diet; carbohydrates and fat are least effective in this respect.

Most effective is a protein diet which raises the BMR, to 30% due to stimulating effect of deaminated fatty acid residues on cellular metabolism. This is known as specific dynamic action.

8. BAROMETRIC PRESSURE:

Until and unless barometric pressure is significantly reduced, the BMR does not alter. When the pressure falls to half an atmosphere, the BMR is reduced by 5-25%. This depends upon the fall in oxygen tension. So when mountain sickness appears, the BMR is reduced.

9. PHYSICAL EXERCISE:

Light exercise, such as sitting, standing, dressing, sewing, etc. increases heat production by 25 60%. Moderate exercise, like walking, swimming, homework, light carpentry increases heat production double fold, i.e, 100-200%. Heavy muscular exercise, as in plumbing, rowing and mining entails heat production, at 10-15 times above the basal level.

10. MENTAL EFFORT:

It does not affect BMR, but heavy mental strain slightly increases BMR (by 4%).

11. EMOTION:

Strong emotion increases BMR, 5-10% above normal value.

12. SLEEP:

During deep sleep BMR is reduced to 10% lower than normal. But disturbed sleep and wakefulness increase the BMR.

13. WEIGHT:

Empirically it is recognised in case of adult animals (both warm blooded and cold blooded) that the metabolic rate changes to % power of their body weights. This is true for elephants as well as mice.

14. ENVIRONMENTAL TEMPERATURE:

Rise of temperature depresses heat production and fall in temperature raises it.

15. DRUGS AND CHEMICAL AGENTS:

Administration of caffeine, thyroxine, adrenaline (less effective than thyroxine), anterior pituitary extract (through effect on thyroid), dinitrophenol, benzidrine raise the BMR.

16. SMOKING:

It has ordinarily no effect on BMR, but inhalation of the smoke increases the BMR by 9% .

B. PATHOLOGICAL:

1. Increased BMR is encountered under the following conditions:

- ❖ Administration of pyrogens, either bacterial or chemical agent.
- ❖ Diseases: Thyrotoxicosis, leukaemia (25-50%), fever due to any cause (it raises BMR 7% per 1° Fahrenheit rise of temperature). Diabetes insipidus, congestive cardiac failure, renal failure, polycythaemia (10-40%) also raise BMR.

2. Decreased BMR is encountered under the following conditions:

- ❖ Nutritional deficiency: starvation and undernutrition
- ❖ Obesity due to pituitary and hypothalamic cause.
- ❖ Hypothyroidism: myxoedema and cretinism.
- ❖ Renal disease: nephrotic syndrome.

CIRCULATION

Circulationisthe movement of blood through the vessels of the body induced by the pumping action of the heart. In 1628 William Harvey first discovered the circulation of the blood.

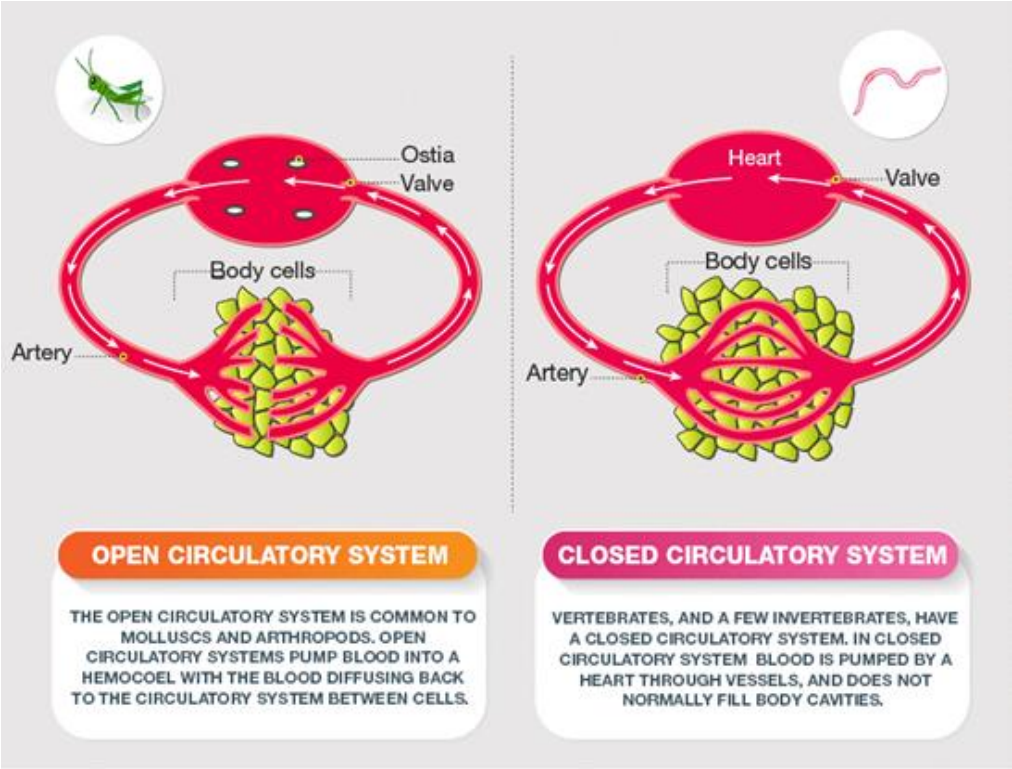
FUNCTIONS OF BLOOD AND CIRCULATION:

- Circulates OXYGEN and removes Carbon Dioxide.
- Provides cells with NUTRIENTS.
- Removes the waste products of metabolism to the excretory organs for disposal.
- Protects the body against disease and infection.
- Clotting stops bleeding after injury.
- Transports HORMONES to target cells and organs.
- Helps regulate body temperature.

CIRCULATORY SYSTEM:

Almost all multicellular organisms need a circulatory system to transport oxygen and nutrients through the body. Evolution has led to the existence of two types of circulatory systems namely:

- **OPEN CIRCULATORY SYSTEM**: primarily found in invertebrates. Here, the blood flows freely through cavities since there are no vessels to conduct the blood.
- **CLOSED CIRCULATORY SYSTEM**: is found in vertebrates and a few invertebrates like earthworms. This system has vessels that conduct blood throughout the body.



OPEN AND CLOSED TYPE OF CIRCULATORY SYSTEM

TYPES OF HEART

HEART:

Heart is the central muscular pumping organ of the circulatory system. It is. It is of the following types:

1. Pulsatile hearts
2. Tubular hearts
3. Chambered hearts
4. Accessory hearts
5. Myogenic hearts and
6. Neurogenic hearts

1. PULSATILE HEARTS:

These are blood vessels exhibiting rhythmic contraction. They are found in Annelids and Amphioxus.

2. TUBULAR HEARTS:

These are in the form of tubes. They are found in Arthropods, Balanoglossus and Ascidians. The tubular hearts are enclosed in a pericardium.

3. CHAMBERED HEARTS:

These hearts are divided into chambers. They are found in vertebrates. In fishes, the heart is two chambered containing one auricle and one ventricle. In amphibians and reptiles, the heart is three chambered containing two auricles and one ventricle. In birds and mammals, the heart is four chambered containing two auricleand two ventricles.

4. ACCESSORY HEARTS:

These are dilated portions of blood vessels. The function as booster pumps and they force the blood with increased pressureto certain organs. They are found in insects, cephalopods, fishes, amphibians and reptiles.

5. MYOGENIC HEARTS:

In the myogenic hearts, the heart beat originates in the muscles of the heart. Acetylcholine inhibits myogenic hearts. The hearts of vertebrates and molluscs are myogenic.In the fishes and amphibians, the heart beat starts at the sinusvenosus. Amongthe birds and mammals, the heart beat starts at the sinu auricular node. If the sinus venosus is removed from the adult amphibian heart, the normal rhythm stops and other regions may take over the initiation. In adult mammalian hearts, local cooling or warming is most effective in altering the rate when applied in the sinu auricular region.

6. NEUROGENIC HEARTS:

In the neurogenic hearts, the heart-beat originates in ganglion cells. Acetylcholine line accelerates the neurogenic hearts. Ether inhibits the neurogenic hearts. The neurogenic hearts have ganglion cells on their dorsal aspect

PHYSIOLOGY OF CARDIAC MUSCLE

The heart muscle is remarkable. At an average heart rate of 70 beats/minutes, the heart needs to contract and relax more than 100 000 times a day without stopping or

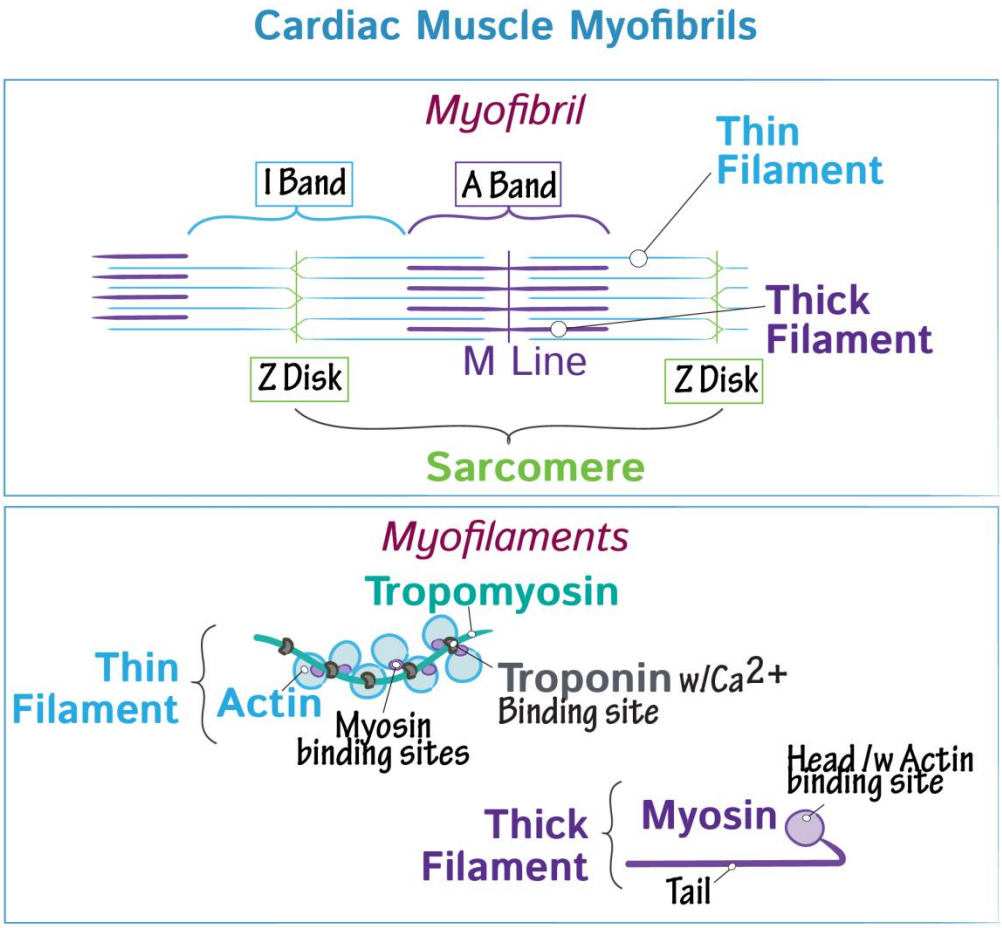
tiring. The rate and strength of these contractions must vary to meet physiological and pathological challenges.

STRUCTURE OF THE CARDIAC MYOCYTE:

Each cardiac myocyte is surrounded by a cell membrane called the sarcolemma and contains one nucleus. The cells are packed with mitochondria to provide the steady supply of ATP required to sustain cardiac contraction. As with skeletal muscle, cardiac myocytes contain the contractile proteins actin (thin filaments) and myosin (thick filaments) together with the regulatory proteins troponin and tropomyosin. Cardiac muscle is striated, although the pattern is not as ordered as in skeletal muscle.

The myofilaments within the myocyte are surrounded by sleeves of sarcoplasmic reticulum, analogous to endoplasmic reticulum found in other cells. Separate tubular structures, the transverse tubules (T tubules), cross the cell. In the cardiac myocyte, the T tubule crosses at the Z-line, in contrast to the A-I junction in skeletal muscle. The lumen of the T tubule is continuous with the extracellular fluid surrounding the cell and, as in skeletal muscle, the action potential is propagated down the T

tubule. Adjacent cardiac myocytes are joined end-to-end at structures known as intercalated disks. These always occur at a Z-line. At these points, the cell membranes form a number of parallel folds and are tightly held together by desmosomes. This results in strong cell-to-cell cohesion, thus allowing the contraction of one myocyte to be transmitted axially to the next. Gap junctions exist between cardiac muscle cells, providing low resistance pathways for the spread of excitation from one cell to another.



RESTING MEMBRANE AND ACTION POTENTIALS:

Cardiac myocytes can be divided into work cells and pacemaker cells. The work cells have a large stable resting membrane potential and display a prolonged action potential with a plateau phase. The pacemaker cells have smaller unstable resting potentials and spontaneously depolarize, generating the intrinsic electrical activity of the heart. Pacemaker cells are found in the sinoatrial (SA) and atrioventricular (AV) nodes. The cells of the bundle of His and some Purkinje cells are also capable of spontaneous firing.

THE CARDIAC ACTION POTENTIAL:

The cardiac action potential has a prolonged plateau phase lasting around 300 ms.The cardiac action potential has five phases. During phase 0, membrane permeability to potassium decreases and fast sodium channels open, producing rapid depolarization. During phase 1, there is partial repolarization, because of a decrease in sodium permeability. Phase 2 is the plateau phase of the cardiac action potential. Membrane permeability to calcium increases during this phase, maintaining depolarization and

prolonging the action potential. Membrane permeability to calcium decreases somewhat towards the end of phase 2, and the plateau is partially maintained by an inward sodium current. Sodium flows into the cell through the sodium–calcium exchanger. The exchanger transfers three sodium ions into the cell in exchange for one calcium ion flowing out, and so produces a net inward positive current. As calcium channels inactivate towards the end of the plateau phase, an inward potassium current produces repolarization in phase 3. The resting membrane potential in phase 4 is produced mainly by the selective permeability of the cell membrane to potassium and the concentration gradient for potassium that exists across the cell membrane. The cardiac action potential lasts about 300 ms. For the vast majority of this time, the cell is absolutely refractory to further stimulation.

THE PACEMAKER POTENTIAL:

The pacemaker potential is seen in cells in the SA and AV nodes. It differs from the action potential of cardiac myocytes, phases 1 and 2 are absent. The heart displays auto rhythmicity: a denervated heart (such as the heart of a cardiac transplant patient) continues to contract

spontaneously. Pacemaker cells do not have a stable resting action potential, and it is the spontaneous depolarization of the pacemaker potential that gives the heart its auto-rhythmicity. The pacemaker potential is produced by a decrease in membrane permeability to potassium, a slow inward current because of calcium influx via T-type (transient) calcium channels, and an increased sodium current because of sodium– calcium exchange. Once the threshold potential is reached, L-type calcium channels open, calcium ions enter the cell, and depolarization occurs. In contrast to the cardiac myocyte action potential, there is no inward movement of sodium ions during depolarization. Repolarization (phase 3 of the action potential) occurs because of an increase in potassium permeability. At the SA node, potassium permeability can be further enhanced by vagal stimulation. This has the effect of hyperpolarizing the cell and reducing the rate of firing. Sympathetic stimulation has the opposite effect.

RATE, CONDUCTION, AND SPEED:

The SA node, other atrial centres, AV node, and bundle of His all have inherent pacemaker activity. The SA

node has the highest rate of spontaneous depolarization and therefore suppresses the other pacemakers. In the denervated heart, the SA node discharges at a rate of approximately 100 times/min. From the SA node, impulses spread throughout the atria to the AV node. The AV node is the only means of electrical connection between the atria and the ventricles. Conduction here is slow. Depolarization spreads from the AV node to the bundle of His in the interventricular septum. The bundle splits into right and left bundle branches, supplying the respective ventricles. The left bundle itself divides into anterior and posterior divisions. From the bundle branches, impulses travel through the ventricular muscle via a network of Purkinje fibres. The conducting system is arranged so that the apices of the ventricles contract before the bases, propelling blood out of the chambers.

EXCITATION CONTRACTION COUPLING (ECC):

The physiological process of converting an electrical stimulus to a mechanical response. Cardiomyocytes are capable of coordinated contraction, controlled through the gap junctions of intercalated discs. The gap junctions spread action potentials to support the synchronized

contraction of the myocardium. In cardiac, skeletal, and some smooth muscle tissue, contraction occurs through a phenomenon known as excitation contraction coupling (ECC). ECC describes the process of converting an electrical stimulus from the neurons into a mechanical response that facilitates muscle movement. Action potentials are the electrical stimulus that elicits the mechanical response in ECC.

CALCIUM-INDUCED CALCIUM RELEASE:

Calcium-induced calcium release (CICR): A process whereby calcium can trigger release of further calcium from the muscle sarcoplasmic reticulum. In cardiac muscle, ECC is dependent on a phenomenon called calcium-induced calcium release (CICR), which involves the influx of calcium ions into the cell, triggering further release of ions into the cytoplasm. The mechanism for CIRC is receptors within the cardiomyocyte that bind to calcium ions when calcium ion channels open during depolarization, releasing more calcium ions into the cell.

Similarly to skeletal muscle, the influx of sodium ions causes an initial depolarization; however, in cardiac muscle, the influx of calcium ions sustains the

depolarization so that it lasts longer. CICR creates a "plateau phase" in which the cell's charge stays slightly positive (depolarized) briefly before it becomes more negative as it repolarizes due to potassium ion influx. Skeletal muscle, by contrast, repolarizes immediately.

PATHWAY OF CARDIAC MUSCLE CONTRACTION

The actual mechanical contraction response in cardiac muscle occurs via the sliding filament model of contraction. In the sliding filament model, myosin filaments slide along actin filaments to shorten or lengthen the muscle fiber for contraction and relaxation. The pathway of contraction can be described in five steps:

- An action potential, induced by the pacemaker cells in the sinoatrial (SA) and atrioventricular (AV) nodes, is conducted to contractile cardiomyocytes through gap junctions.
- As the action potential travels between sarcomeres, it activates the calcium channels in the T-tubules, resulting in an influx of calcium ions into the cardiomyocyte.
- Calcium in the cytoplasm then binds to cardiac troponin-C, which moves the troponin complex away from the actin

binding site. This removal of the troponin complex frees the actin to be bound by myosin and initiates contraction.

- The myosin head binds to ATP and pulls the actin filaments toward the center of the sarcomere, contracting the muscle.
- Intracellular calcium is then removed by the sarcoplasmic reticulum, dropping intracellular calcium concentration, returning the troponin complex to its inhibiting position on the active site of actin, and effectively ending contraction as the actin filaments return to their initial position, relaxing the muscle.

ORIGIN OF HEART BEAT:

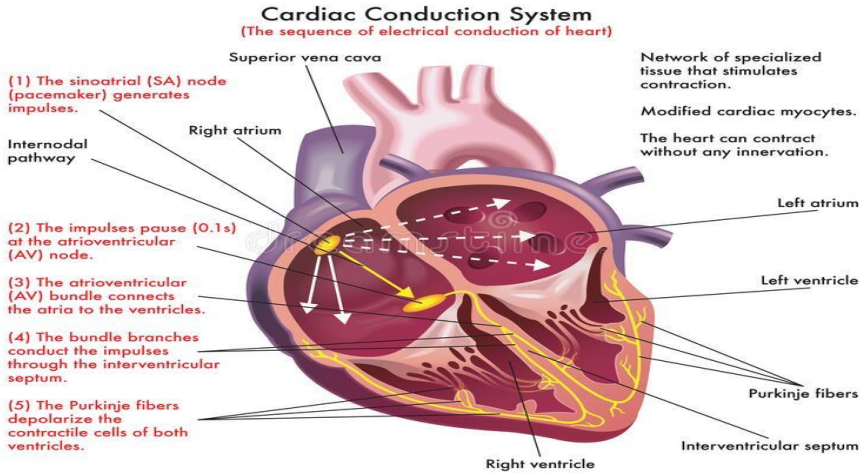
The parts of the heart normally beat in orderly sequence: Contraction of the atria (atrial systole) is followed by contraction of the ventricles (ventricular systole), and during diastole all four chambers are relaxed. The heartbeat originates in a specialized cardiac conduction system and spreads via this system to all parts of the myocardium. The structures that make up the conduction system are the sinoatrial node (SA node), the internodal atrial pathways, the atrioventricular node (AV node), the bundle of His and its branches, and

the Purkinje system. The various parts of the conduction system and, under abnormal conditions, parts of the myocardium, are capable of spontaneous discharge**.** However, the SA node normally discharges most rapidly, with depolarization spreading from it to the other regions before they discharge spontaneously. The SA node is therefore the normal cardiac pacemaker, with its rate of discharge determining the rate at which the heart beats. Impulses generated in the SA node pass through the atrial pathways to the AV node, through this node to the bundle of His, and through the branches of the bundle of His via the Purkinje system to the ventricular muscle. Each of the cell types in the heart contains a unique electrical discharge pattern; the sum of these electrical discharges can be recorded as the electrocardiogram (ECG).

SINOATRIAL NODE:

SA node is a small, flattened mass of neuromuscular tissue, about 3mm wide, 15mm long and 1mm thick. It is situated near the opening of superior venacava in right atrium. Sinus nodal fibers connects directly with the atrial muscle fibers so that any action potential that begins in the sinus node transmits immediately into atrial muscle

wall. The fibers of SA node has ability of self-excitation and control the rate of entire heartbeat.



The **fibers of SA node** have high concentration of Sodium ions in extracellular fluid and negative charges inside the nodal fibers. Due to high concentration and the presence of open channels, Na^+ ions always tends to enter inside. The membrane permeability of K^+ is gradually reduced which upsets the ionic balance of Na and K making the interior more positive. Ultimately at threshold (approx. -40mV), fast Ca^{++} channels open allowing entry of Calcium and some Sodium form extracellular space. The increase in Ca++ produces rising phase of action potential and reverses the membrane potential. In this way excitation wave or electrical waves are generated.

At regular intervals, the wave of contraction spreads all over the atria. The SA node sets the pace for the heart as a

whole. Hence it is the heart's pacemaker. The fibers of SA node are closely associated with atrial muscle hence action potential generated at SA node travels throughout the atria. This ultimately stimulates AV node through internodal pathway which is present in the posterior wall of septum of right atrium.

ATRIOVENTRICULAR NODE:

AV node is a small mass of neuromuscular tissue located in the wall of atrial septum near atrio-ventricular valves. At AV node impulse is delayed for about 0.1 sec allowing the atria to complete their contraction before the ventricles contract. The AV node is also capable of initiating impulses of contraction but at slower rate than SA node.

Atrioventricular bundle / AV bundle / Bundle of His is a mass of specialized fibers originating from AV node. AV bundle crosses the fibrous ring that separate atria and ventricle. And divides into right and left branches at upper end of septum. Within the ventricular myocardium these branches breaks down into fine purkinjefibers. **Purkinje fibers** convey impulses of contraction from AV node to the apex of myocardium where the wave of ventricular

contraction begins and sweeps upwards, pumping blood into pulmonary artery and aorta

REGULATION OF HEARTBEAT:

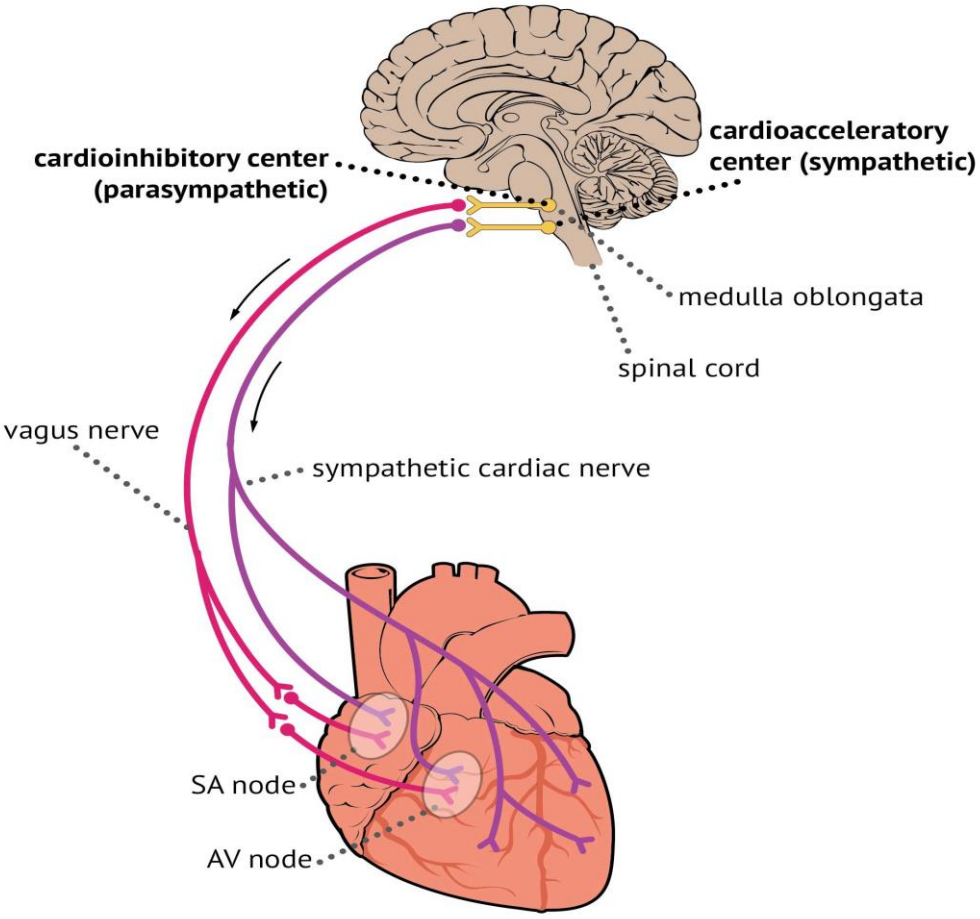
Heartbeat is regulated by both hormonal and nervous control.

A.NERVOUS CONTROL:

Heart is abundantly supplied with parasympathetic (vagus) and sympathetic nerve fibers. Impulse originated in heart is increased by Sympathetic nervous system (SNS) and decreased by parasympathetic nervous system (PNS). Stimulation of right vagus slows the heart by inhibiting SA node wheres stimulation of left vagus slows AV conduction.

THE AUTONOMIC NERVOUS SYSTEM:

The ANS is responsible for controlling many physiological functions: inducing the force of contraction of the heart, peripheral resistance of blood vessels and the heart rate. The ANS has both sympathetic and parasympathetic divisions that work together to maintain balance.



NERVOUS CONTROL

PARASYMPATHETIC:

The parasympathetic input into the heart is via the vagus nerve (CN X). The vagus nerve forms synapses with postganglionic cells in SAN and AVN. When stimulated, acetylcholine which binds on to M_2 receptors, which acts to decrease the slope of the pacemaker potential, leading to a decrease in heart rate (a negative chronotropic effect).

SYMPATHETIC:

The sympathetic input into the heart is via the postganglionic fibres from the sympathetic trunk which innervate the SAN and AVN. The post ganglionic fibres release noradrenaline, which acts on B_1adrenoreceptors to increase the slope of the pace maker potential, thereby increasing the heart rate (a positive chronotropic effect), as well as increasing the force of contraction (positive inotropic effect).

The parasympathetic input on the SAN dominates at rest, to give a normal resting heart rate of around 60bpm. Any initial increases in heart rate are brought about by a reduction in parasympathetic outflow, and increasing the heart rate over 100bpm is via an increase in sympathetic outflow.

BARORECEPTOR REFLEX:

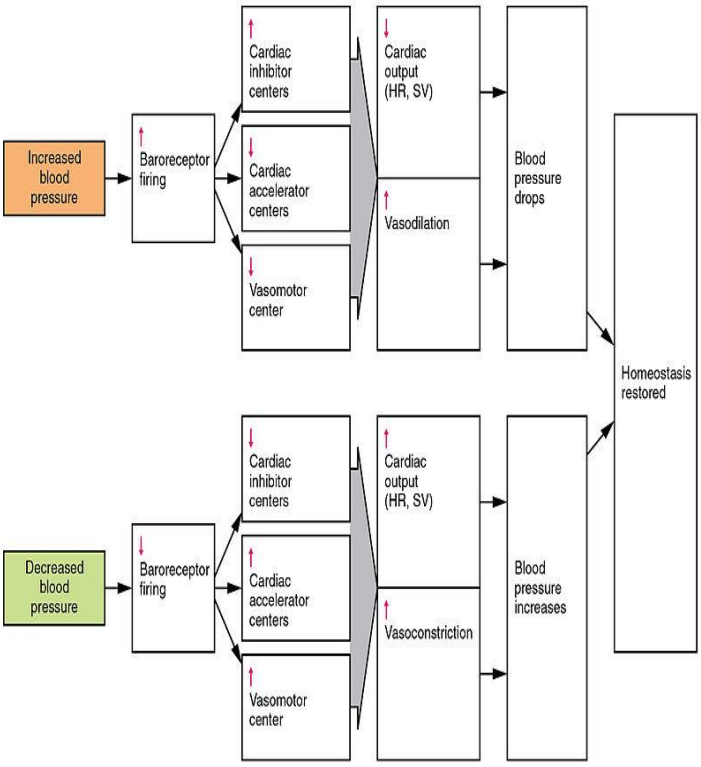
Baroreceptors are mechanoreceptors located in both the carotid sinus and the aortic arch, which are sensitive to stretch.

Their function is to detect changes in arterial pressure and communicate this to the medulla oblongata in the brainstem. The medullary centres in the brain are

responsible for the overall output of the autonomic nervous system, and use the information fed back from baroreceptors to coordinate a response:

If an increased arterial pressure is detected, the parasympathetic pathway is activated to reduce heart rate. This, along with increasing vasodilation of vessels, acts to reduce the arterial pressure.

If a decrease in arterial pressure is detected, the sympathetic pathway is activated to increase the heart rate and the force of contraction of the heart. This, along with increasing vasoconstriction of vessels, acts to increase the arterial pressure.



BARORECEPTOR REFLEX

B.HORMONAL CONTROL:

Hormones also have the ability to affect the heart rate. One example would be adrenaline, which is released from the medulla of adrenal glands. This hormone can be released into the blood stream at a time when a person encounters a stressful situation. The release of this hormone can result in a number of effects one of which is increasing of the heart rate.

Following hormones regulates heartbeat and blood pressure:-

- 1.The renin-angiotensin-aldosterone system of the kidneys regulates blood volume. In response to rising blood pressure, the juxtaglomerular cells in the kidneys secrete renin into the blood. Renin converts the plasma protein angiotensinogen to angiotensin I, which in turn is converted to angiotensin II by enzymes from the lungs.
- 2.Angiotensin II constricts blood vessels throughout the body (raising blood pressure by increasing resistance to blood flow). Constricted blood vessels reduce the amount of blood delivered to the kidneys, which decreases the

kidneys' potential to excrete water (raising blood pressure by increasing blood volume).

- Angiotensin II stimulates the adrenal cortex to secrete aldosterone, a hormone that reduces urine output by increasing retention of water and Na + by the kidneys (raising blood pressure by increasing blood volume).
- 3.Epinephrine and norepinephrine, hormones secreted by the adrenal medulla, raise blood pressure by increasing heart rate and the contractility of the heart muscles and by causing vasoconstriction of arteries and veins. These hormones are secreted as part of the fight-or-flight response.
- 4.Antidiuretic hormone (ADH), a hormone produced by the hypothalamus and released by the posterior pituitary, raises blood pressure by stimulating the kidneys to retain water (raising blood pressure by increasing blood volume).
- 5.Thyroid hormones raise the heart rate and contraction force.

BLOOD COAGULATION

The conversion of liquid blood into semisolid at the bleeding site is called coagulation. Coagulation is also called clotting. The semi-solid blood is called clot.

Coagulation is of great biological value in the survival of animals. When one receives a cut in the skin, the blood flows for a short while and then it clots there preventing its further flow. Thus the clot acts as a plug, thereby sealing the gap in the injured blood vessel which prevents further bleeding. If a portion of the blood clot is examined, it shows a number of thread like structures forming a network which is formed of a protein called fibrin. In the meshes of the threads RBC and WBC are seen entangled. However, there are different opinions regarding the mechanism of coagulation. The important mechanisms can be explained by the following theories:

1. Enzyme cascade theory
2. Best and Taylor's theory
3. Howell's theory
4. Fuld and Spiro's theory.

1. ENZYME CASCADE THEORY:

Enzyme cascade theory explains the coagulation of blood. This theory was proposed by Biggs and Macfarlane in 1966. Enzyme cascade refers to a series of enzyme

catalysed reactions, each reaction initiating the next, until the final step is reached.

To stop bleeding, the body relies on the interaction of three processes: Primary hemostasis involves the first two processes.

1. VASOCONSTRICTION:

Vasoconstriction is the body's first response to injury in the vascular wall. When injury occurs, vessel walls constrict, causing reduced blood flow to the site of injury. Vasospasm of the blood vessels occurs first in response to injury of the vasculature. This vasospasm, in turn, stimulates vasoconstriction. Vasoconstriction is primarily mediated by endothelin-1, a potent vasoconstrictor, which is synthesized by the damaged endothelium. Damaged endothelium exposes sub-endothelial collagen, von Willebrand factor (vWF), releases ATP, and inflammatory mediators. vWF is synthesized by megakaryocytes which later gets stored in a-granules of platelets. Weibel-Palade bodies of the endothelium also synthesize vWF. It is the combination of exposure of vWF, subendothelial collagen, ATP, and inflammatory mediators which provide the

gateway into the second phase of primary hemostasis, platelet adhesion.

2. PLATELET PLUG.

Platelets aggregate to the site of the injury. They stick together acting as a "plug." Platelets also activate the process which causes a fibrin clot to form, known as secondary hemostasis. Platelet adhesion is the process by which platelets attach to the exposed subendothelialvWF. Post vascular damage, platelets begin to roll along vessel walls and adhere to areas of exposed subendothelial collagen and vWF. Platelet membranes are rich in G protein (Gp) receptors located within the phospholipid bilayer. Specifically, it is GpIb-IX receptor on platelets that bind to vWF within the endothelium that creates the initial connection between the two. Once bound, a variety of events can occur in the third phase of primary hemostasis to activate the platelet.

Platelet activation consists of platelets undergoing two specific events once they have adhered to the exposed vWF (i.e. the damaged vessel site). First, platelets will undergo an irreversible change in shape from smooth discs to multi-pseudopodal plugs, which greatly increases their

surface area. Second, platelets secrete their cytoplasmic granules.

Platelet activation is mediated via thrombin by two mechanisms. Thrombin directly activates platelets via proteolytic cleavage by binding the protease-activated receptor. Thrombin also stimulates platelet granule release which includes serotonin, platelet activating factor, and Adenosine Diphosphate (ADP). ADP is an important physiological agonist which is stored specifically in the dense granules of platelets. When ADP is released, it binds to P2Y1 and P2Y12 receptors on platelet membranes. P2Y1 induces the pseudopod shape change and aids in platelet aggregation. P2Y12 plays a major role in inducing the clotting cascade. When ADP binds to its receptors, it induces GpIIb/IIIa complex expression at the platelet membrane surface. The GpIIb/IIIa complex is a calcium-dependent collagen receptor which is necessary for platelet-to-endothelial adherence and platelet-to-platelet aggregation. Simultaneously, platelets synthesize Thromboxane A2 (TXA2). TXA2 further intensifies vasoconstriction and platelet aggregation (next step in the primary hemostasis process). The process of platelet

activation readies the local environment for platelet aggregation.

Platelet aggregation begins once platelets have been activated. Once activated, the GpIIb/IIIa receptors adhere to vWF and fibrinogen. Fibrinogen is found in the circulation and forms a connection between the GpIIb/IIIa receptors of platelets to interconnect them with each other. This ultimately forms the weak platelet plug.

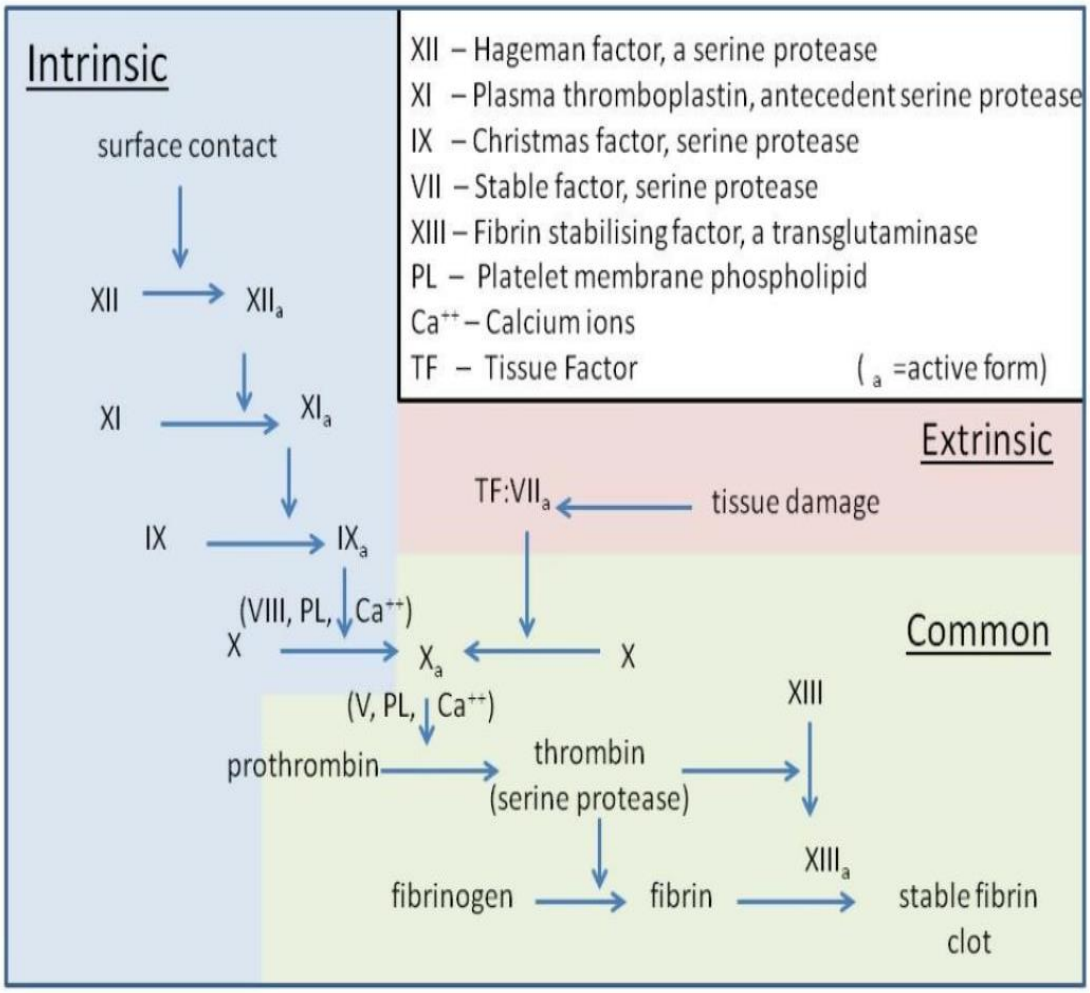
Ultimately, primary hemostasis allows the culmination of a weak platelet plug to temporarily protect from hemorrhage until further stabilization of fibrinogen to fibrin via thrombin occurs in secondary hemostasis.

SECONDARY HEMOSTASIS:

Secondary hemostasis involves the clotting factors acting in a cascade to ultimately stabilize the weak platelet plug. This is accomplished by completing three tasks: (1) triggering activation of clotting factors, (2) conversion of prothrombin to thrombin, and (3) conversion of fibrinogen to fibrin. These tasks are accomplished initially by 1 of 2 pathways; the extrinsic and intrinsic pathway, which converge at the activation of factor X and then complete their tasks via the common pathway. Please note that

calcium ions are required for the entire process of secondary hemostasis. The clotting cascade occurs through two separate pathways that interact, the intrinsic and the extrinsic pathway.

The three pathways that makeup the classical blood coagulation pathway



EXTRINSIC PATHWAY:

The extrinsic pathway includes tissue factor (TF) and factor VII (FVII). It is initiated when TF binds to FVII, activating FVII to factor VIIa (FVIIa), forming a TF-FVIIa

complex. This complex, in turn, activates factor X (FX). Note, the TF-FVIIa complex can also activate factor IX of the intrinsic pathway, which is called the alternate pathway. Once Factor X is activated to FXa by TF-FVIIa complex, the cascade continues down the common pathway.

INTRINSIC PATHWAY:

The intrinsic pathway includes Hageman factor (FXII), factor I (FXI), factor IX (FIX), and factor VIII (FVIII). The process is initiated when FXII comes into contact with exposed subendothelial collagen and becomes activated to FXIIa. Subsequently, FXIIa activates FXI to FXIa, and FXIa activates FIX to FIXa. FIXa works in combination with activated factor VIII (FVIIIa) to activate factor X. Once Factor X is activated by FIXa-FVIIIa complex, the cascade continues down the common pathway.

COMMON PATHWAY:

The common pathway is initiated via the activation of Factor Xa. Factor Xa combines with Factor Va and calcium on phospholipid surfaces to create a prothrombinase complex ultimately activating prothrombin

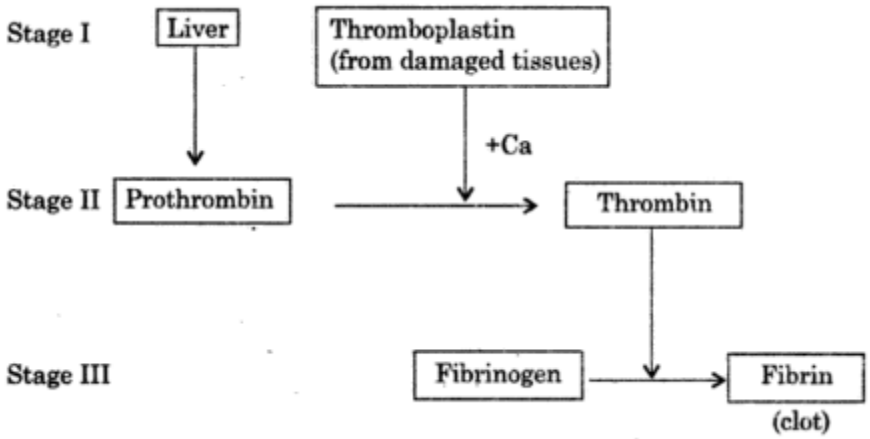
(aka Factor II) into thrombin. This activation of thrombin occurs via serine protease cleaving of prothrombin. Now, thrombin activates factor XIIIa (FXIIIa). FXIIIa crosslinks with fibrin forming the stabilized clot. Finally, the clot must be dissolved in order for normal blood flow to resume following tissue repair.

BLOOD CLOT:

Blood clot is the mass of coagulated blood containing fibrin mesh RBCs, WBCs and platelets. The blood cells are trapped in the mesh work. The external blood clot appearing on the wound is called scab. The blood clot formed inside the blood vessel is called thrombus. The clotting of blood inside the blood vessels is called thrombosis. The clot contracts in 30 to 45 minutes. The contraction of clot is called clot retraction. During clot retraction a straw coloured fluid oozes out of the clot. This fluid is called serum. Lysis of blood clot inside the blood vessel is called fibrinolysis. Fibrinolysis helps to remove clot from the lumen of blood vessel. Fibrinolysis is brought about by plasmin.

2. BEST AND TAYLOR'S THEORY:

According to Best and Taylor, four substances, namely prothrombin, calcium, thromboplastin and fibrinogen are taking part in coagulation. The plasma of the circulating fluid contains prothrombin. Thromboplastin is present in the tissues. Calcium occurs in plasma. Fibrinogen occurs in a dissolvedstate in the plasma.When blood is shed, the injured tissues liberate thromboplastin. In the presence of Ca++ions, prothrombin is converted into active thrombin. Then thrombin acts upon soluble fibrinogen, converting it into insoluble fibrin.



The circulating fluid does not clot inside the blood vessels because of the non-availability of free thromboplastin in the blood. But, when thrombin is formed by chance, it is neutralised at once by another substance, namely antithrombin.

3. HOWELL'S THEORY:

According to Howell, Ca++ alone is promoting the conversion of prothrombininto thrombin.Because of the presence of antithrombin in the blood, the prothrombin is prevented from activation.When there is an injury, the formed elements of the blood at once release a substance known as cephalin. The cephalin neutralises the activity of antithrombin and allows Ca++ to react with prothrombin. This results in the formation of thrombin which converts fibrinogen to fibrin.

4. FULD AND SPIRO'S THEORY:

Fuld and Spiro considered thrombokinase, produced(platelets), converts prothrombin into thrombin.

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CHAPTER - III

(EXCRETION AND OSMOREGULATION)

Excretion - excretion of metabolic waste products in relation to the environment - physiology of excretion in Man Iono - osmoregulation in Invertebrates (crustaceans), fishes, birds and mammals -hormonal control.

Mr. P. ARPUTHARAJ M.Sc.

Research Scholar

Dept. Adv. Zoology & Biotech

Loyola College

Chennai

E.Mail: arputharaj.9111@gmail.com

EXCRETION

Excretion, the process by which animals rid themselves of waste products and of the nitrogenous by-products of metabolism. Osmoregulation is the maintenance of constant osmotic pressure in the fluids of an organism by the control of water and salt concentration.

Through excretion organisms control osmotic pressure—the balance between inorganic ions and water—and maintain acid-base balance. The process thus promotes homeostasis, the constancy of the organism's internal environment.

Every organism, from the smallest protist to the largest mammal, must rid itself of the potentially harmful by-products of its own vital activities. This process in living things is called elimination, which may be considered to encompass all of the various mechanisms and processes by which life forms dispose of or throw off waste products, toxic substances, and dead portions of the organism. The nature of the process and of the specialized structures developed for waste disposal vary greatly with the size and complexity of the organism. Four terms are commonly associated with waste-disposal processes and

are often used interchangeably, though not always correctly: excretion, secretion, egestion, and elimination.

Excretion is a general term referring to the separation and throwing off of waste materials or toxic substances from the cells and tissues of a plant or animal. The separation, elaboration, and elimination of certain products arising from cellular functions in multicellular organisms is called secretion. Though these substances may be a waste product of the cell producing them, they are frequently useful to other cells of the organism.

Examples of secretions are the digestive enzymes produced by intestinal and pancreatic tissue cells of vertebrate animals, the hormones synthesized by specialized glandular cells of plants and animals, and sweat secreted by glandular cells in the skins of some mammals. Secretion implies that the chemical compounds being secreted were synthesized by specialized cells and that they are of functional value to the organism. The disposal of common waste products should not, therefore, be considered to be of a secretory nature.

Egestion is the act of excreting unusable or undigested material from a cell, as in the case of single-

celled organisms, or from the digestive tract of multicellular animals. As defined above, elimination broadly defines the mechanisms of waste disposal by living systems at all levels of complexity. The term may be used interchangeably with excretion.

EXCRETION OF METABOLIC WASTE PRODUCTS IN RELATION TO THE ENVIRONMENT

Waste disposal by unicellular and multicellular organisms is vital to their health and to the continuance of life. Animals must take in (ingest) energy-containing chemical compounds, extract a portion of the energy to power their life processes, and dispose of the unusable material or by-products formed during the energy-extraction process. An analogous series of events occurs in an internal-combustion engine. Fuel, containing energy, is taken into the engine, where it is burned, and a portion of the energy released is used to move the pistons.

As in living cells, a portion of the energy-containing material (fuel) not utilized in the engine is exhausted in the form of carbon monoxide, carbon dioxide, and other by-products of combustion. Blockage of the exhaust system in

an engine results in loss of efficiency and eventual total breakdown. Similarly, the rate of waste disposal in biological systems can and does provide a means of controlling the metabolic rate. Complete blockage of waste-disposal mechanisms in living systems is as effective in destroying vital functions as the cutting off of food, oxygen, or water from the system.

In addition, some substances produced as metabolic by-products are toxic in themselves and must be removed from living cells at a rate equal to that at which they are produced by those cells. Thus, the excretion of waste products from living cells must occur continually in order to ensure the normal progression of vital chemical events.

Waste and poisonous substances produced by the metabolic activities of plant and animal communities must, in a similar manner, be removed or detoxified if community health is to be preserved. Collective wastes of individual organisms constituting a community, if allowed to accumulate to any marked degree, will eventually destroy the lives of all the community members.

The biosphere, composed of all individuals and communities of life forms and their environments on the

Earth, is equally sensitive to the effects of waste and poison accumulation. A continual build-up of substances harmful to life forms can only result in the eventual destruction of most or all of the presently existing species of plants and animals.

Humans are unique among living things in that their activities result in the production of waste materials (pollutants) that, by virtue of their chemical structure, are poisonous to all living things, including themselves.

TYPES OF WASTE: METABOLIC AND NON-METABOLIC

Waste products may be categorized as metabolic or non-metabolic. The difference lies in whether the substances in question are produced by the chemical processes of a living cell or are merely passed through the digestive tract of an organism without actually entering into its life processes.

NON-METABOLIC WASTES

The non-metabolic wastes are mainly materials that, by virtue of their chemical makeup, are indigestible or unusable by an organism. In addition, non-metabolic wastes include any substances that are absorbed, ingested,

or otherwise taken into a living system in excess of the needs and storage capabilities of the organism. These substances include digestible (metabolizable) as well as indigestible materials, and they may be excreted almost immediately, even though they are often usable as food.

METABOLIC WASTES

Metabolic wastes may be separated into gases, liquids, solids, and heat. Heat, though usually not classified as a waste product, should be classified as such because it is a by-product of metabolic activity and must be eliminated to avoid harmful elevation of body temperatures in warm-blooded animals.

GASEOUS WASTES

Oxygen produced during photosynthetic reactions in green plants and certain bacteria may be considered to be a waste product, or at least a by-product, requiring removal. Carbon dioxide is produced by all animals and by green plants in darkness. Nitrogen gas is produced by denitrifying sulfur bacteria (*Thiobacillus*), and ammonia is excreted by decay-causing bacteria and by most invertebrate and vertebrate animals.

LIQUID WASTES

The sole liquid waste produced as a metabolic by-product by all animals and photosynthetic plants in darkness is water.

SOLID WASTES

Several important kinds of materials may be classified as solid wastes. Among them are nitrogenous wastes, by-products of protein and amino-acid metabolism by animals; nitrite and nitrate compounds produced by nitrifying bacteria; and sulfur and sulfates resulting from the metabolic activities of sulfur bacteria. Many other substances also enter into solid wastes to be disposed of by organisms.

Iron compounds in an insoluble form are secreted by iron bacteria that have used soluble iron compounds. Various resins, fats, waxes, and complex organic chemicals are exuded from certain plant as in the latex from rubber trees and milkweeds. Organic pigments from the breakdown of biological pigments, such as hemoglobin in vertebrates, become components of solid waste. Inorganic salts, including molecules and ions such as carbonates, bicarbonates, and phosphates resulting from

life-sustaining chemical reactions, eventually may become solid waste products.

METHODS OF WASTE DISPOSAL

Disposal of metabolic and non-metabolic wastes involves both active and passive mechanisms. In general, gaseous wastes are eliminated through passive mechanisms without the direct expenditure of energy on the part of the living system.

The solid and liquid waste-disposal mechanisms used by higher animals are active (energy consuming) systems that separate waste materials from vital substances prior to excretion. Methods of disposal may be classified into specific and nonspecific systems.

PHYSIOLOGY OF EXCRETION IN MAN

SPECIFIC ELIMINATION MECHANISMS

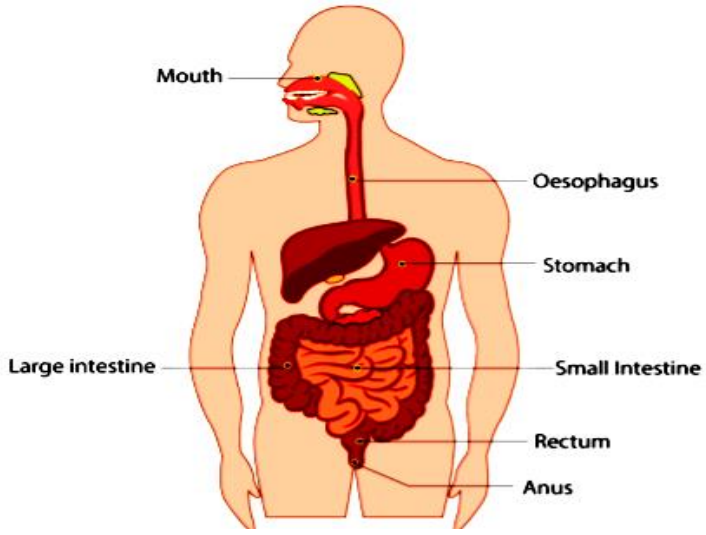
Three pathways exist in this context:

1) the alimentary canal
2) the respiratory system, and
3) Specifically the excretory system is mainly carried by a pair of kidneys, a pair of ureters, a urinary bladder and a urethra

ALIMENTARY CANAL

The alimentary canal is a pathway used almost exclusively for the elimination of solid wastes of an indigestible nature, and the act of elimination by this means is termed egestion. Materials disposed of in this manner have not entered the tissues of the animal but rather are the residues of enzymatic and absorptive activities occurring in the digestive tract.

True metabolic wastes are excreted by means of the flow of bile from the liver into the intestine. The destruction of cells in animals produces bile pigments—residues of hemoglobin and other pigments—which may be considered to be the principal metabolic wastes eliminated via the alimentary canal.



Digestive system - alimentary canal of Human

Waste disposal in this manner requires little energy expenditure other than that employed in the peristaltic contractions of muscle in the walls of the tract that act to push material along the length of the tube.

RESPIRATORY SYSTEM

The respiratory pathway is concerned principally with the gaseous waste products of metabolism (carbon dioxide and ammonia), which move to the external environment by diffusing from the cells of origin. In invertebrate and vertebrate members of the animal kingdom, transport is by means of the circulatory system when present or simply by diffusion through the cell membranes of lower animals.

A few multicellular aquatic animals lose carbon dioxide to the surrounding water by way of diffusion through the thin vascular membranes of their general body surface. In higher animals, however, the skin is too hard or thick and nonvascular to function effectively in gas disposal. In these animals, gills and lungs—aggregations of thin, moist, vascular membranes—have evolved.

Membranes of the gills of aquatic animals and the lungs of terrestrial forms are provided with large surface areas for the diffusion of waste gases from the circulatory

system to the outside environment. Because carbon dioxide is soluble in the body water, it can easily diffuse into the circulatory system, in solution, from the cells of origin. Transport and excretion of carbon dioxide requires little energy as it diffuses along concentration gradients from cells to the circulation and finally to the outside environment.

Because more carbon dioxide (CO_2) is produced by metabolic activity than can be carried in the circulatory system in the form of dissolved carbon dioxide, the major portion of carbon dioxide is transported to the gills and lungs as bicarbonate (HCO_3), via two chemical reactions:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-.$$

Thus, carbon dioxide reacts with water, producing carbonic acid (H_2CO_3), which in turn dissociates to produce a hydrogen ion (H^+) and a bicarbonate ion (HCO_3^-). In the lungs or gills, these reactions occur in the opposite direction, and carbon dioxide diffuses from the body into the outside environment. Certain aquatic animals are capable of eliminating gaseous ammonia—derived from protein breakdown—by way of specialized cells in their gill tissues.

Salt secretion via specialized gill cells occurs in marine vertebrates that constantly absorb salt through thin membranes of their oral, respiratory, and body surfaces.

THE KIDNEYS

Kidneys have evolved in multicellular animals as a highly sophisticated channel for waste disposal, and they function to regulate the levels of water, salts, and organic materials in the bodies of higher animals. Materials eliminated via the kidney include nitrogenous waste products (ammonia, uric acid, urea, creatine, creatinine, and amino acids), excess quantities of salts and water that may be taken into the body, and various other organic materials produced by life-sustaining chemical reactions.

Functionally, the kidney is a microfilter that initially removes dissolved as well as some suspended materials from the circulatory system, along with large quantities of water. These substances are differentially reabsorbed into the blood by various kidney structures during urine formation to a degree that varies considerably throughout the animal kingdom. For example, animals that absorb large quantities of water into their bodies (such as freshwater fishes) excrete copious quantities of water in

their urine. The reverse is true of many desert animals, who must conserve water and therefore produce a thick, semisolid urine. The kidney, in its various stages of evolution, functions at the expense of considerable metabolic energy and cannot be considered to be a passive system.

STRUCTURE OF KIDNEY

The structure of the kidney is explained below:

CAPSULE

The outer layer is called the capsule. Inside the kidney, there are two zones- the outer zone is the cortex and the inner zone is the medulla. The cortex extends in between the medullary pyramids as renal columns called columns of Bertin.

NEPHRONS

Nephrons are the functional units of the kidney. Each nephron has two parts- glomerulus and renal tubule. Glomerulus consists of a bunch of capillaries formed by afferent arterioles. Blood from glomerulus is carried away by efferent arterioles. The renal tubule starts with a cup-like structure called Bowman's capsule and this encloses the glomerulus. The malpighian body consists of

glomerulus and Bowman's capsule. The highly coiled structure in the tubule next to the Bowman's capsule is the proximal convoluted tubule.

HENLE'S LOOP

The next part of the tubule is Henle's loop which has an ascending and a descending limb. The ascending loop continues as a distal convoluted tubule. The distal convoluted tubules of many nephrons open into the collecting duct. The cortical region of the kidney comprises of malpighian corpuscle, proximal convoluted tubule and distal convoluted tubule and the medullary region contains a loop of Henle.

There are two types of nephrons – cortical and juxtamedullary. In the case of cortical, the loop of Henle is very short and extends only a little into the medulla. In juxtamedullary, the loop of Henle is very long and runs deep into the medulla.

URETER

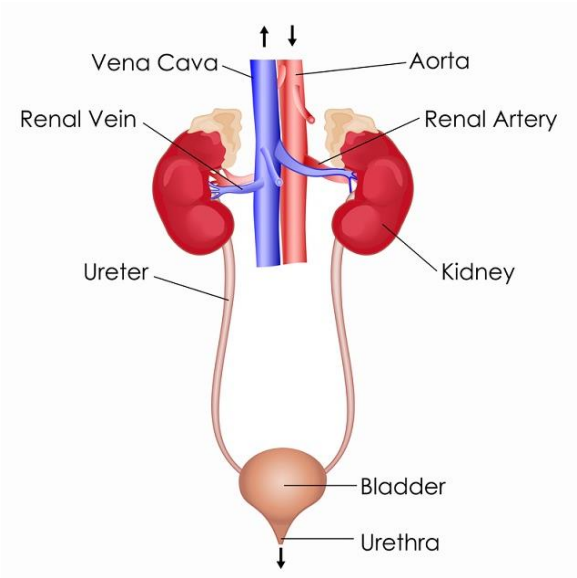
A pair of thin muscular tubes called the ureter comes out of each kidney extending from the renal pelvis. It carries urine from the kidney to the urinary bladder.

URINARY BLADDER

It is a muscular sac-like structure, which stores urine. The urinary bladder is emptied by the process of micturition, i.e. the act of urination.

URETHRA

This tube arises from the urinary bladder and helps to expel urine out of the body. In males, it acts as the common route for sperms and urine. Its opening is guarded by sphincter muscles.



The excretory system of Human

EXCRETION IN HUMANS

Excretion is the process where all the metabolic wastes are removed from the body. Excretion in humans is carried through different body parts and internal organs in a series of processes. Diffusion is the most common process of excretion in lower organisms.

A human body is an exceptional machine, where different life-processes (respiration, circulation, digestion, etc.) take place simultaneously. As a result, many waste products produced in our body are in various forms that include carbon dioxide, water, and nitrogenous products like urea, ammonia, and uric acid.

In addition to these, the chemicals and other toxic compounds from medications and hormonal products are also produced. Simple diffusion is not sufficient to eliminate these wastes from our body. We need more complex and specific processes in order to eliminate waste products.

Blood contains both useful and harmful substances. Hence, we have kidneys which separate useful substances by reabsorption and toxic substances by producing urine. Kidney has a structural filtration unit called nephron where the blood is filtered. Each kidney contains a million

nephrons. Capillaries of kidneys filter the blood and the essential substances like glucose, amino acids, salts, and the required amount of water get reabsorbed and the blood goes into circulation.

Excess water and nitrogenous waste in humans are converted to urine. Urine thus produced is passed to the urinary bladder via the ureters. The urinary bladder is under the control of the Central Nervous System. The brain signals the urinary bladder to contract and through the urinary opening called the urethra, we excrete the urine.

MECHANISM OF EXCRETION IN HUMANS

The process of excretion in humans takes place in the following steps:Urine Formation

The urine is formed in the nephrons and involves the following steps:

- Glomerular Filtration
- Tubular Reabsorption
- Secretion

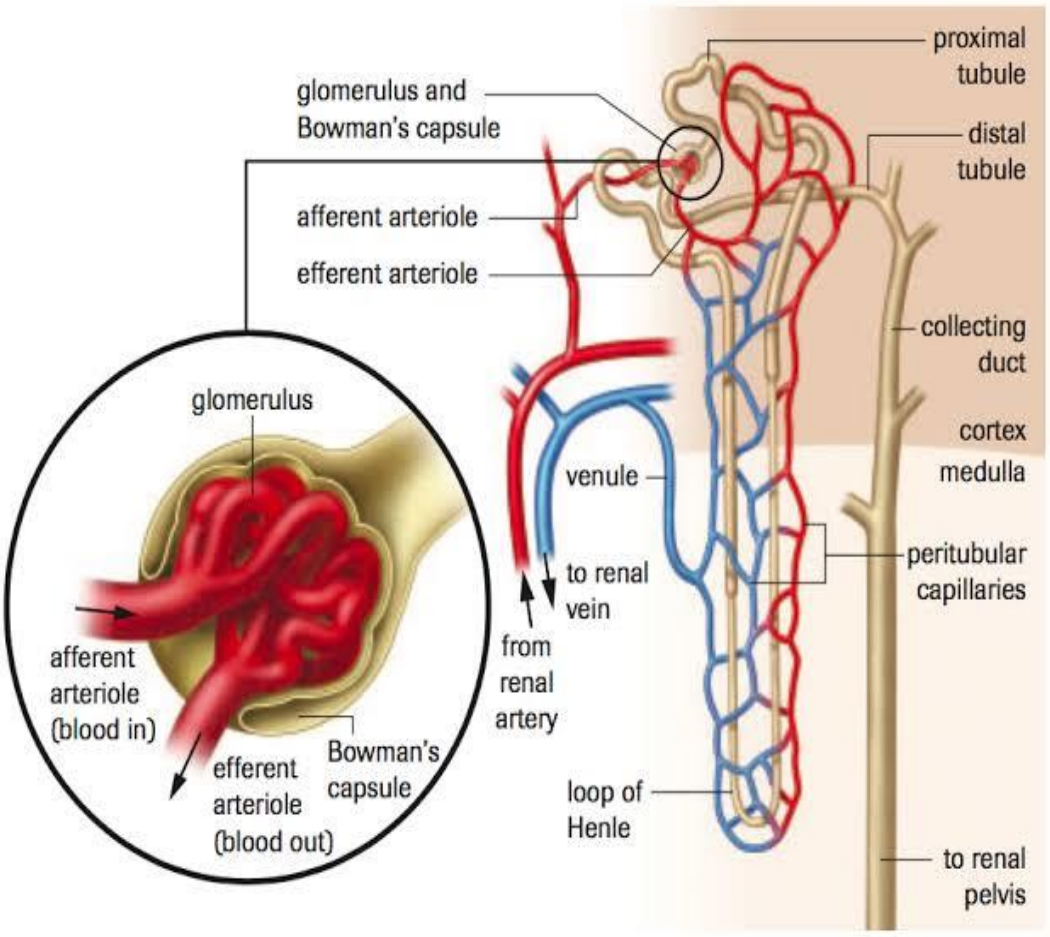
GLOMERULAR FILTRATION

It is the primary step in urine formation. In this process, the excess fluid and waste products from the kidney are filtered out of the blood into the urine collection

tubules of the kidney and eliminated out of the body. The amount of filtrate produced by the kidneys every minute is known as Glomerular Filtration Rate (GFR).

TUBULAR REABSORPTION

It is the absorption of ions and molecules such as sodium ions, glucose, amino acids, water etc. Water involves passive absorption, while glucose and sodium ions are absorbed by an active process.



Secretion process

SECRETION

Potassium ions, hydrogen ions, and ammonia are secreted out to maintain the equilibrium between the body fluids.

The functions of the various tubules involved in the process are:

- **Glomerulus**- filters the blood
- **Proximal Convoluted Tubules (PCT)**- reabsorb water, ions and nutrients. They remove toxins and help in maintaining the ionic balance and pH of the body fluids by secretion of potassium, hydrogen and ammonia to filtrate and reabsorbing bicarbonate ions from the filtrate.
- **Descending Loop of Henle**- is permeable to water and the filtrate gets concentrated as it is impermeable to electrolytes.
- **Ascending Loop of Henle**- it is impermeable to water and permeable to electrolytes. The filtrate gets diluted due to the movement of electrolytes from the filtrate to the medullary fluid.
- **Distal Convoluted Tubule (DCT)**- allows reabsorption of water and sodium ions. It also helps in maintaining pH and ionic balance by secretion and reabsorption of ions like PCT.

- **Collecting Duct**- a large amount of water is reabsorbed from the filtrate by the collecting duct.

MICTURITION

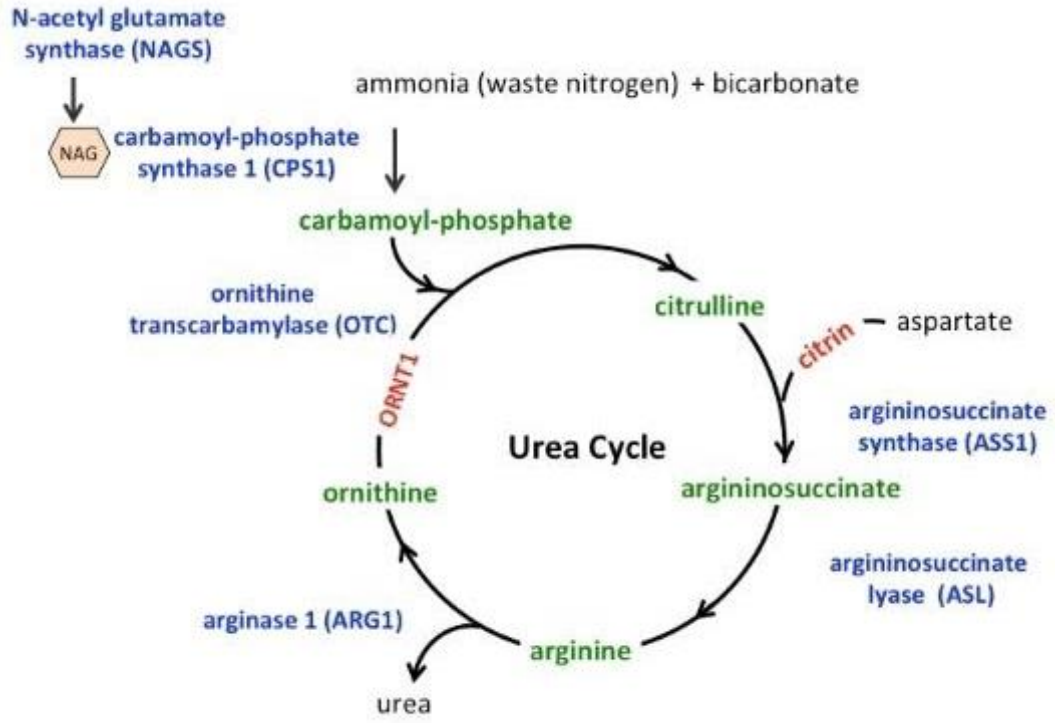
The urinary bladder is stretched and gets filled with urine formed in the nephrons. The receptors present on the walls of the urinary bladder send signals to the Central Nervous System, thereby, allowing the relaxation of sphincter muscles to release urine. This is known as micturition.

UREA CYCLE

Unlike glucose, there is no storage form of amino acids. Amino acids are degraded into free ammonia (NH^{4+}) and the carbon skeleton. Living organisms excrete excess nitrogen as ammonia, uric acid, and urea. The urea cycle is also known as the Ornithine cycle. It is a cycle of biochemical reactions occurring in many animals that produces urea ($(NH_2)_2CO$) from ammonia (NH_3). This cycle was the first metabolic cycle discovered (Hans Kre Kurt Henseleit, 1932), five years before the discovery of the TCA cycle.

In mammals, the urea cycle takes place primarily in the liver, and to a lesser extent in the kidney. The urea

cycle takes place in the mitochondria and the cytosol. There are four enzymes involved, three of which are cytosolic and one is mitochondrial. In the mitochondria, carbamoyl phosphate is catalyzed by carbamoyl phosphate synthetase (CPS I). Carbamoyl phosphate is formed by condensing and activating bicarbonate and ammonia.



The urea cycle

Two ATP is also required. It is the first acquirement of nitrogen. The carbamoyl group of carbamoyl phosphate is transferred to ornithine giving citrulline. The reaction is catalyzed by ornithine transcarboxylase. Citrulline is then

transported out to the cytosol. Now in the cytosol, citrullyl-AMP is formed.

Adding aspartate displaces AMP to form argininosuccinate, where urea's second nitrogen is acquired. It is catalyzed by argininosuccinatesynthetase. Arginine, urea's immediate precursor, is then made by the removal of fumarate from argininosuccinatecatalyzed by argininosuccinase.

In the final reaction, urea is formed by cleaving off the carbon backbone of arginine by arginase. Ornithine is also made, which is transported back into the mitochondria. Fumarate from argininosuccinate is converted to aspartate for reuse in the argininosuccinatesynthetase reaction. The formation of urea costs more than three high energy bonds. The urea cycle ultimately yield 6 ATPs.

REGULATION OF THE UREA CYCLE

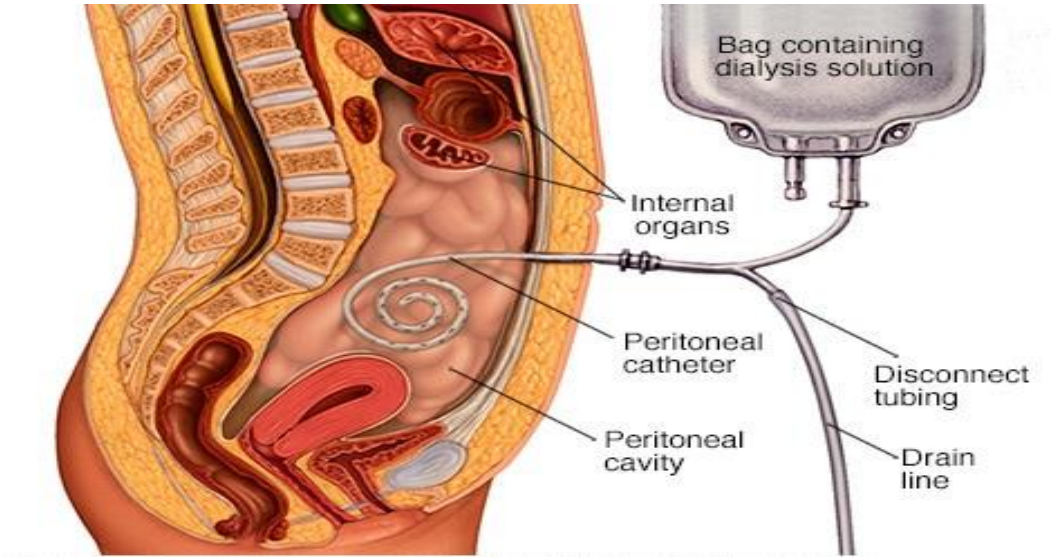
Urea catabolism is regulated on two levels. During prolonged starvation, muscle proteins are broken down to supply energy, therefore production of urea increases significantly. The enzymes involved in the urea cycle are

also synthesized at higher rates. In the short term, CPS I is allosterically regulated.

DIALYSIS

Under certain circumstances such as poor blood flow to the kidneys, infections, injuries, etc. the kidneys fail to perform their functions. In such situations, artificial kidneys are used for blood filtration and this process is called dialysis.

Other than the urinary system, skin, lungs, and even eyes helps in excreting waste products in different forms. Sweating is a mode of excretion where water, urea, and other salts are excreted through the skin. Lungs help us to exhale gaseous wastes such as carbon dioxide, nitrogen, etc.



Dialysis process in human

NON-SPECIFIC MECHANISMS OF WASTE DISPOSAL

A multitude of disposal mechanisms exist throughout the plant and animal kingdoms for the elimination of excess plant and animal material. Among plants, the shedding and dropping of bark, leaves, and twigs might, in a broad sense, be said to represent disposal mechanisms. Certain plants, in addition, secrete or exude resins, sap, and other substances that accumulate in excessive quantities within the plant.

Specialized, mobile, amoeba-like cells exist in the blood and tissues of animals and engulf particulate wastes resulting from the disintegration of dead cells or the intake of foreign particles into the bodies of animals. Waste matter thus stored inside these small cells is removed from contact with the organism or its metabolism and may be considered to be eliminated whether or not the material is ever actually eliminated from the body of the organism during its normal life cycle.

Toxic substances are produced by normal metabolic activities. Though some of these poisons are eliminated in their original chemical form, others, such as some

nitrogenous compounds, are altered biochemically to less toxic compounds. In this manner, more of the original waste may be safely stored, or permitted to accumulate without harmful effects to the organism, until it can be eliminated. In addition, toxic chemicals that are inadvertently ingested or produced by bacterial action (infection) are frequently converted to nontoxic forms by enzymatic and antibody (immune) reactions. Such materials can then be eliminated safely with other wastes along normal pathways of excretion.

Heat is eliminated from the bodies of animals by conduction to the external surface of the organism. In animals possessing a circulatory system, heat travels in its fluid from the deeper portions of the body to the surface. At the body surface, heat is lost by physical processes of convection, radiation, conduction, and evaporation of sweat.

COMPARATIVE OVERVIEW OF ELIMINATORY MECHANISMS FROM PROTISTS TO VERTEBRATES

PROTISTA

No specialized elimination mechanisms are present in algae, fungi, protozoans, and slime molds, the main groups of protists. Metabolic wastes (carbon dioxide, water, oxygen, and nitrogenous compounds) diffuse through the cell membranes of these unicellular organisms into the outside environment. Particulate wastes pass from the bodies of certain protozoans to the exterior by way of small openings in the body surface—anal pores and other cell openings. Elimination in protists is carried out passively and therefore requires little or no expenditure of metabolic energy on the part of the organism.

PLANTS

Plants are not generally considered to possess special mechanisms of elimination. Photosynthetic activities of green plants, in the presence of light, produce oxygen, which diffuses out through openings in the leaves (stomata) or through the cell walls of roots and other plant structures. Excess water passes to the exterior via similar

routes and is eliminated by processes of guttation (droplet exudation) and transpiration (evaporation of water from plant surfaces).

Green plants in darkness or plants that do not contain chlorophyll produce carbon dioxide and water as respiratory waste products. Carbon dioxide is secreted in the same manner as oxygen via diffusion through stomata and cell walls. Materials that are exuded by some plants—resins, saps, latexes, etc.—are forced from the interior of the plant by hydrostatic pressures inside the plant and by absorptive forces of plant cells. These forces are passive in nature, and exudation requires no energy expenditure on the part of the plant.

ANIMALS

Diverse mechanisms have evolved that enable the various animal species to inhabit a wide range of environments. In animals whose bodies consist of a single layer of cells, waste disposal is accomplished principally by diffusion from the site of waste production to the outside environment. This method is efficient when the distances over which wastes diffuse are relatively short, when there is a high surface area to volume relationship,

and when the rate of waste production is relatively low. In more complex animals, however, waste elimination by diffusion through the body wall to the exterior is less efficient because individual cells are farther removed from the exterior surface of the organism. The presence of specialized mechanisms of elimination in higher animals enables wastes to be rapidly transported to the exterior surface of the body.

SPONGES

Phylogenetically, the sponges (phylum Porifera) are the simplest of animals. They are multicellular and composed of specialized cells, arranged in a single layer, for the maintenance of life processes. Elimination in these aquatic animals' proceeds by diffusion of gaseous wastes into the surrounding water and by the ejection of solid wastes and indigestible material from the digestive cells into the streams of water that constantly flow through the animal.

CNIDARIANS

The jellyfishes, coral animals, ctenophores, and comb jellies have a rudimentary canallike cavity in their two-layered bodies for the ingestion, digestion, and egestion of

food and wastes. Gaseous wastes are eliminated by diffusion, and solid wastes in dissolved or undissolved form pass out through an opening in the body wall that serves the dual purposes of food intake and waste elimination.

FLATWORMS

Flatworm bodies consist of three layers of cells, and in this aquatic group elimination is similar to that of the less complex animals. Food and solid wastes enter and leave through a common opening in the well-developed digestive tract, which consists of a mouth, pharynx, and gastrovascular cavity.

NEMERTINE WORMS

The digestive and excretory system of the aquatic proboscis worms is more efficient than that of lower animals in that a well-defined mouth, intestine, and excretory opening (anus) permit the one-way flow of food and waste through the animal. Egested food and nitrogenous wastes, which are secreted into the intestine, are passed along it to the anus by peristaltic waves of the smooth muscle lining the intestinal walls. The efficiency of waste elimination is increased by the presence of a well-

defined circulatory system, which enhances the carriage of wastes to the intestine.

NEMATODES

An additional excretory structure has evolved in the roundworms. Excretory canals located on both sides of the intestine facilitate waste disposal by carriage of material to an excretory pore in the body wall.

OTHER INVERTEBRATES

In invertebrates, increasing structural complexity is accompanied by more efficient waste-disposal mechanisms. In the phylum Mollusca (clams, snails, oysters, mollusks, octopuses, and squids), gills add another more efficient channel for waste disposal. A heart increases the rate of flow in the circulatory system and speeds the transport of wastes to the gills. An excretory, kidneylike organ removes metabolic wastes from the circulation and body fluid prior to excretion. All basic mechanisms of excretion are thus present in relatively simple animals. As invertebrates become more specialized and complex, as in the arthropods (insects, crabs, and other joint-legged animals) and annelids (segmented worms),

adaptations in excretion methods allow survival in nonaquatic environments.

VERTEBRATES

Though the wastes produced by vertebrates differ little qualitatively from those of higher invertebrates, increased structural complexity and body size, in combination with environmental adaptations, require more specific waste-disposal mechanisms in order to maintain a constant internal environment. The presence of highly efficient, water-retaining kidneys, for example, permits vertebrates to inhabit arid, hot regions of the earth. It seems proper, within the vertebrate group, to consider elimination schemes as variations of mechanisms common to all higher animals but which enable animals to inhabit widely diversified environments.

INVERTEBRATE EXCRETORY SYSTEMS

In their detoxication mechanisms, so far as they have been investigated, the invertebrates in general conform to the principles applying to all animals, namely, that aquatic forms get rid of ammonia by diffusion through the surface of the body; terrestrial forms convert ammonia to uric acid. This implies that in aquatic forms the excretory organ is

principally of importance for the composition of their body fluids. Normally, the body fluids of marine invertebrates have the same concentration as seawater; they usually differ, however, in the proportions of ions, with relatively more potassium and less magnesium than seawater.

Furthermore, their urine normally has the same concentration as seawater, but correspondingly it contains less potassium and more magnesium. In freshwater invertebrates the urine is commonly, though not invariably, more dilute than the body fluids. By producing dilute urine a freshwater invertebrate conserves the salt content of its body while eliminating the water that enters its body by osmosis through its water-permeable surface.

Some invertebrates, notably echinoderms, cnidarians, and sponges, have no organs to which an excretory function can be confidently ascribed. Since all of these animals are aquatic, it is reasonable to suppose that they excrete nitrogen (as ammonia) by simple diffusion. Their body fluids (where present) are closely similar to seawater in composition, and it may be presumed that regulation operates only at the cellular level.

The excretory organs of other invertebrates are of diverse evolutionary origin. This is not to say, however, that each invertebrate phylum has evolved its own particular type of excretory organ; rather, there appear to be five main types of invertebrate excretory organ: contractile vacuole, nephridium, renal gland, coxal gland, and malpighian tubule.

THE CONTRACTILE VACUOLES OF PROTOZOANS

Some protozoan animals possess an organelle having the form of an internal sac, or vacuole, which enlarges by the accumulation of a clear fluid and then discharges its contents to the exterior. The cycle of filling and emptying may be repeated as frequently as every half minute. The chief role of the contractile vacuole appears to be in osmotic regulation, not in nitrogen excretion.

Contractile vacuoles occur more frequently and are more active in freshwater species than in closely related marine species. In fresh water, the concentration of dissolved substances in the cell is greater than in the external medium, and the cell takes in water by osmosis. If the contractile vacuole is put out of action, the cell

increases in volume. If the concentration of salts in the medium increases—which would have the effect of decreasing the rate of osmosis—the rate of output by the contractile vacuole diminishes. The fluid eliminated by the vacuole is more dilute than the cytoplasm.

THE NEPHRIDIA OF ANNELIDS, NEMERTINES, FLATWORMS, AND ROTIFERS

The word nephridium applies in its strict sense only to the excretory organs of annelids, but it may usefully be extended to include the excretory organs of other phyla having similar characteristics. Annelids are segmented animals that typically contain a pair of nephridia on each segment. Each nephridium has the form of a very fine tubule, often of considerable length; one end usually opens into the body cavity and the other to the exterior. In some annelids, however, the tubule does not open into the body cavity but ends internally in a cluster of cells of a special type known as solenocytes, or flame cells. The possession of solenocytes by some annelids is one of the characteristics that allies them with other nonsegmented phyla that have no true body cavity. They also have a system of tubules opening at the surface and ending

internally in flame cells embedded among the other cells of the body. In most cases, there is no regular arrangement of the various parts of the system. Animals belonging to all of these phyla are primarily aquatic, and, in the few cases known, the main excretory product is ammonia. How much of it leaves the body by the nephridia and how much through the body surface is not known.

Few physiological studies have been made on nephridia other than those of the earthworm. Although the earthworm is considered a terrestrial animal, its relationships with its environment are characteristically those of a freshwater animal. The nephridium of the earthworm is longer and more complex than that of marine annelids, four regions being distinguishable. Body fluid enters the nephridium via an internal opening called the nephridiostome. As the fluid passes along the tubule, probably driven by cilia, its composition is modified. In the two lower regions of the tubule the fluid becomes progressively more dilute, presumably as a result of the reabsorption of salts. Finally, a very dilute urine passes into the bladder (an enlarged portion of the tubule) and then to the exterior through the external opening, or

nephridiopore. The rate of urine flow for an earthworm may be as much as 60 percent of its body weight in a period of 24 hours. Learn More!

THE RENAL GLANDS OF MOLLUSKS

The anatomical form of the renal gland varies from one class of mollusks to another, but a common plan is clearly evident. The renal gland is a relatively wide tube opening from a sac (the pericardium) surrounding the heart, at one end, and to the mantle cavity (effectively to the exterior) at the other. There is a single pair of renal glands; in some forms one member of the pair may be reduced or absent. Clams have the simplest arrangement; the region nearest to the pericardium has glandular walls and gives way to a nonglandular, wider tube that extends to the urinary opening.

The vast majority of mollusks are aquatic and excrete nitrogen in the form of ammonia. In octopuses, however, nitrogen is excreted as ammonium chloride, which is quite strongly concentrated in the urine. Terrestrial snails and slugs excrete uric acid but may also excrete ammonia when living in moist surroundings.

In all mollusks so far investigated the primary process in urine production appears to be filtration of the blood. This may take place through the wall of the heart into the pericardium, or from blood vessels that supply the glandular part of the renal gland. The composition of the primary urine may be altered by reabsorption or secretion, or both. In freshwater mollusks salts are reabsorbed in the glandular tube and in the wide tubule, and the final urine is more dilute than the blood. The rate of urine flow is high, up to 45 percent of the body weight per day in the freshwater mussel. In marine mollusks the urine has the same concentration as the blood, but (in the few cases examined) its ionic composition is different.

THE COXAL GLANDS OF AQUATIC ARTHROPODS

Coxal glands are tubular organs, each opening on the basal region (coxa) of a limb. Since arthropods are segmented animals, it is reasonable to suppose that the ancestral arthropod had a pair of such glands in every segment of the body. In modern crustaceans there is, as a rule, only a single pair of glands, and in higher crustaceans these open at the bases of the antennae. Each antennal

gland is a compact organ formed of a single tubule folded upon itself.

When unraveled the tubule is seen to comprise three or four easily recognizable regions. The tubule arises internally as a small sac, the coelomic sac, which opens into a wider region, the labyrinth, having complex infoldings of its walls. The labyrinth opens either directly into the bladder, as in marine lobsters and crabs, or into a narrow part of the tubule, the canal, which in turn opens into the bladder, as in freshwater crayfishes.

The coelomic sac, well supplied with blood vessels, gives evidence that the primary process in urine production is filtration of the blood through the wall of the coelomic sac in a manner analogous to filtration in the glomerulus and Bowman's capsule of the vertebrate kidney (see below). In lobsters and marine crabs the urine in all parts of the organ has the same ion concentration as the blood. In freshwater crayfishes the urine has the same concentration as far as the end of the labyrinth; from that point on reabsorption takes place in the canal and the urine leaves the body as a very dilute solution.

The addition of the canal to the system demonstrates one way crustaceans have adapted to life in fresh water. But this is not the only way in which the regulatory problem is solved in freshwater crustaceans. In freshwater crabs, for example, there is a great decrease in the water permeability of the surface (principally the gills) so that water enters by osmosis quite slowly.

In contrast to the rate of urine flow in a freshwater crayfish (about 5 percent of the body weight per day), that of the freshwater crab is 100 times less (about 0.05 percent). In the crab the urine has the same concentration as the blood, but because the flow is so small the salt loss via the urine is negligible. A few semiterrestrial crabs are known to produce urine more concentrated than the blood.

In all crustaceans for which analyses are available the concentrations of ions in blood and urine differ. At a urine flow of 5 percent of the body weight per day the activities of the antennal glands are certainly capable of effecting changes in the composition of the blood. These activities are somehow coordinated with salt uptake by the cells of the body surface so as to subserve homeostasis. The role of

the antennal glands in nitrogenous excretion seems to be unimportant.

THE MALPIGHIAN TUBULES OF INSECTS

Although some terrestrial arthropods (e.g., land crabs, ticks) retain the coxal glands of their aquatic ancestors, others, the insects, have evolved an entirely different type of excretory system. The malpighian tubules, which vary in number from two in some species to more than 100 in others, end blindly in the body cavity (which is a blood space) and open not directly to the exterior but to the alimentary canal at the junction between midgut and hindgut. The primary urine issuing from the malpighian tubules has to pass through the rectum before it leaves the insect's body, and in the rectum its composition is markedly changed. The insect excretory system therefore comprises the malpighian tubules and the rectum acting together.

The malpighian tubules are bathed in the insect's blood, but since they are not rigid it is impossible for any hydrostatic pressure to be developed across their walls, such as could bring about filtration. The primary urine is formed by a process of secretion in the following way:

Potassium ions are actively transported from the blood into the cavity of the tubule and are necessarily followed by negatively charged ions so as to maintain electroneutrality. In turn, water follows the ions, probably by osmosis, and various other substances—sugars, amino acids, and urate ions—also enter the primary urine by diffusion from the blood.

The primary urine, together with soluble products of digestion and insoluble indigestible matter from the midgut, then passes to the rectum. There (or in some insects at an earlier stage) the urine is acidified and the soluble urate is thereby converted to insoluble uric acid, which comes out of solution.

Water is then reabsorbed together with the soluble products of digestion and other useful substances, including the bulk of the ions that entered the primary urine. In insects that live in dry surroundings the rectum has remarkable powers of reabsorption, its contents finally being voided as hard, dry pellets containing solid uric acid.

The activity of the excretory system in insects is under hormonal control. This has been most clearly demonstrated in the case of Rhodnius, a bloodsucking bug.

Immediately after the ingestion of a blood meal there is a rapid flow of urine whereby most of the water taken in with the blood meal is eliminated. The distension of the body after ingestion is the stimulus that causes certain cells in the central nervous system to release a hormone that acts upon the malpighian tubules to promote a brisk flow of primary urine.

BIRDS AND REPTILES

The main excretory product of birds and reptiles is uric acid. Since their glomeruli are relatively small, so also is their daily volume of urine. Not highly concentrated by mammalian standards—although it may be turbid with crystals of uric acid—the urine of birds and reptiles is conducted not to a urinary bladder but to the terminal portion of the alimentary canal, the cloaca; from the cloaca it is voided with the feces.

Like mammals, and unlike the lower vertebrates, birds and reptiles have skins impermeable to water and thus are well adapted to terrestrial life. The relative inability of the kidney to produce concentrated urine is compensated for in birds that possess salt glands, which remove excess salt from their bodies. These organs are modified tear glands

that discharge a concentrated solution of sodium chloride through the nostrils. Salt glands enable marine birds to drink seawater with no ill effects.

AMPHIBIANS

Direct evidence for the occurrence of filtration at the glomerulus was first provided by experiments on the amphibian kidney. Although amphibians are formally given the status of terrestrial animals, they are poorly adapted to life on land. They excrete nitrogen in the form of urea and cannot produce urine more concentrated than the blood. Their skins are permeable to water. On land amphibians are liable to lose water very rapidly by evaporation. In fresh water they suffer entry of water by osmosis, which is counteracted by the excretion of a large volume of dilute urine. The urine is stored in a large bladder before being voided, providing a reserve of water the animal can use when it comes on land.

When an amphibian leaves the water, a number of physiological adjustments are made that have the effect of conserving water. The rate of glomerular filtration is reduced by restriction of the blood supply, and this together with an increased release of antidiuretic hormone

results in the production of a small volume of urine of the same concentration as the blood. Antidiuretic hormone (ADH, also known as vasopressin, which increases the permeability of the distal and collecting tubules to water) also increases the permeability of the bladder to water and allows the stored urine to be reabsorbed into the body.

FISHES

The homeostasis problem is the same for freshwater fishes as for other freshwater animals. Water enters the body by osmosis and salts leach out. To compensate, the kidney (which has large glomeruli) produces a relatively large amount of dilute urine (about 20 percent of the body weight per day). This serves to remove the water but by itself is insufficient to prevent gradual loss of salts. Extremely diluted salts are taken up from the fresh water and transported directly into the blood by certain specialized cells in the gills. Nitrogenous excretion is no problem: some ammonia is carried away in the large volume of dilute urine, but most of it simply escapes to the external medium by diffusing through the gills.

By contrast, the homeostasis problem of marine fishes is unlike that of most marine animals. The salt content of the blood of marine fishes is less than half that of seawater (see below Evolution of the vertebrate excretory system); consequently, marine fishes tend to lose water and gain salt. This, it would seem, could be compensated most easily by the excretion of urine more concentrated than the blood, but the kidneys of fishes are not able to do this.

In marine bony fishes the kidney has small glomeruli and produces only a small amount (about 4 percent of the body weight per day) of urine, which is of the same concentration as the blood. The fish replaces its lost water by continually swallowing seawater, and the special cells of the gills, working in reverse, reject salt to the external medium. Nitrogen is excreted mostly as ammonia but also as another detoxication product, trimethylamine oxide.

In sharks and rays ammonia is converted to urea, and urea plays an important role in homeostasis. Urea is retained in the blood to such an extent that the blood is slightly more concentrated than seawater. Thus loss of water by osmosis is prevented and these fish have no need to swallow seawater. Any excess of salt in their bodies is

removed via the rectal gland, functionally analogous to the salt gland of birds.

Osmotic and ionic regulation in fishes is under hormonal control. This has been studied particularly in fishes such as eels and salmon, which are able to move between fresh water and seawater.

HORMONAL REGULATION OF THE EXCRETORY SYSTEM

Maintaining a proper water balance in the body is important to avoid dehydration or over-hydration (hyponatremia). The water concentration of the body is monitored by osmoreceptors in the hypothalamus, which detect the concentration of electrolytes in the extracellular fluid. The concentration of electrolytes in the blood rises when there is water loss caused by excessive perspiration, inadequate water intake, or low blood volume due to blood loss. An increase in blood electrolyte levels results in a neuronal signal being sent from the osmoreceptors in hypothalamic nuclei.

The anterior pituitary is composed of glandular cells that secrete protein hormones. The pituitary gland has two

components: anterior and posterior. The posterior pituitary is an extension of the hypothalamus. It is composed largely of neurons that are continuous with the hypothalamus.

ANTIDIURETIC HORMONE (ADH)

The hypothalamus produces a polypeptide hormone known as antidiuretic hormone (ADH), which is transported to and released from the posterior pituitary gland. The principal action of ADH is to regulate the amount of water excreted by the kidneys. As ADH (which is also known as vasopressin) causes direct water reabsorption from the kidney tubules, salts and wastes are concentrated in what will eventually be excreted as urine.

The hypothalamus controls the mechanisms of ADH secretion, either by regulating blood volume or the concentration of water in the blood. Dehydration or physiological stress can cause an increase of osmolarity above threshold levels, which, in turn, raises ADH secretion and water retention, causing an increase in blood pressure.

ADH travels in the bloodstream to the kidneys where it changes the kidneys to become more permeable to water

by temporarily inserting water channels, aquaporins, into the kidney tubules. Water moves out of the kidney tubules through the aquaporins, reducing urine volume. The water is reabsorbed into the capillaries, lowering blood osmolarity back toward normal. As blood osmolarity decreases, a negative feedback mechanism reduces osmoreceptor activity in the hypothalamus; ADH secretion is reduced. ADH release can be reduced by certain substances, including alcohol, which can cause increased urine production and dehydration.

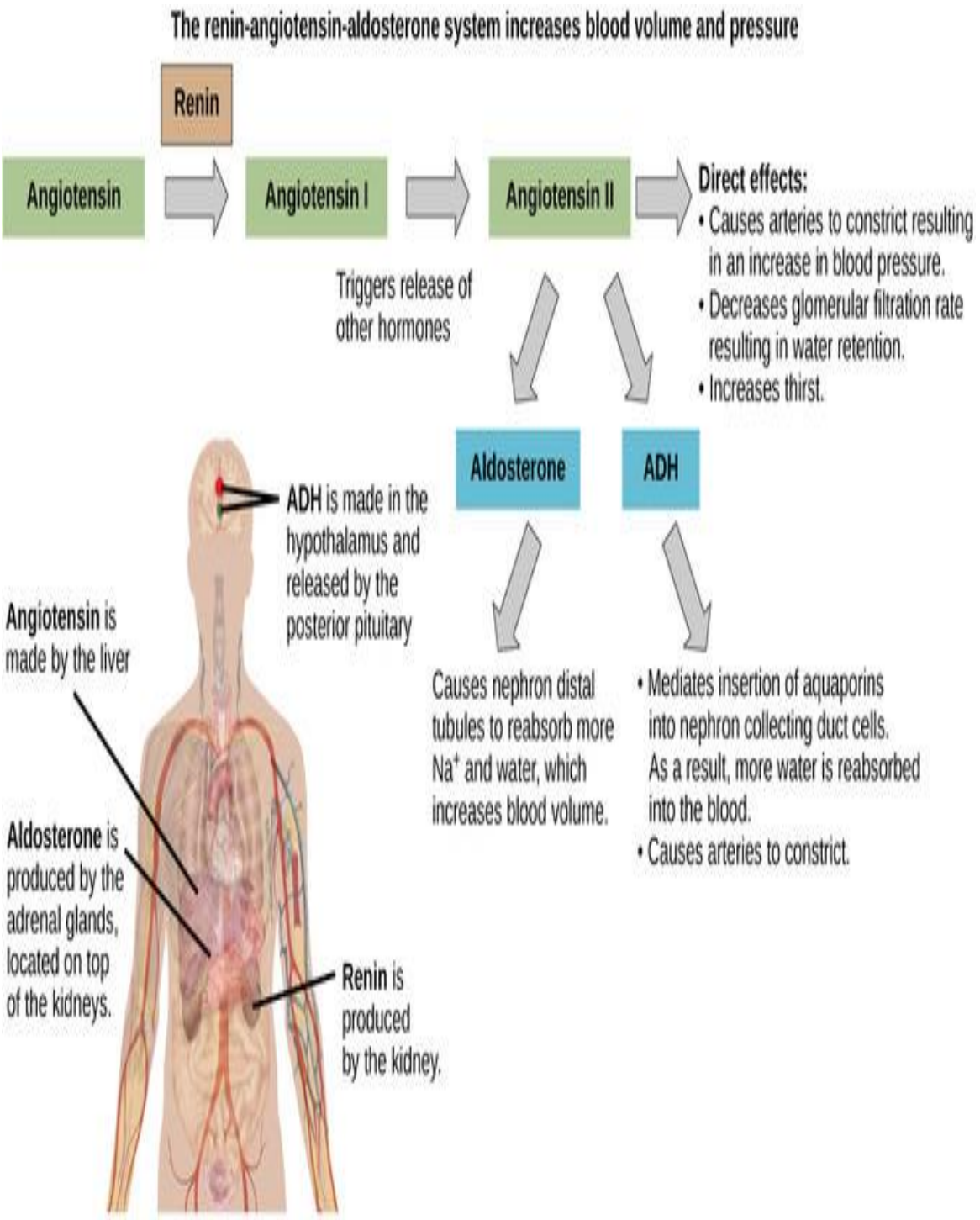
Chronic underproduction of ADH or a mutation in the ADH receptor results in diabetes insipidus. If the posterior pituitary does not release enough ADH, water cannot be retained by the kidneys and is lost as urine. This causes increased thirst, but water taken in is lost again and must be continually consumed. If the condition is not severe, dehydration may not occur, but severe cases can lead to electrolyte imbalances due to dehydration.

Another hormone responsible for maintaining electrolyte concentrations in extracellular fluids is aldosterone, a steroid hormone that is produced by the adrenal cortex. In contrast to ADH, which promotes the

reabsorption of water to maintain proper water balance, aldosterone maintains proper water balance by enhancing Na^+ reabsorption and K^+ secretion from extracellular fluid of the cells in kidney tubules. Because it is produced in the cortex of the adrenal gland and affects the concentrations of minerals Na^+ and K^+, aldosterone is referred to as a mineralocorticoid, a corticosteroid that affects ion and water balance. Aldosterone release is stimulated by a decrease in blood sodium levels, blood volume, or blood pressure, or an increase in blood potassium levels. It also prevents the loss of Na^+ from sweat, saliva, and gastric juice. The reabsorption of Na^+ also results in the osmotic reabsorption of water, which alters blood volume and blood pressure.

Aldosterone production can be stimulated by low blood pressure, which triggers a sequence of chemical release. When blood pressure drops, the renin-angiotensin-aldosterone system (RAAS) is activated. Cells in the juxtaglomerular apparatus, which regulates the functions of the nephrons of the kidney, detect this and release renin. Renin, an enzyme, circulates in the blood, reacting with a plasma protein produced by the liver called

angiotensinogen. When angiotensinogen is cleaved by renin, it produces angiotensin I, which is then converted into angiotensin II in the lungs. Angiotensin II functions as a hormone, causing the release of the hormone aldosterone by the adrenal cortex, resulting in increased Na+ reabsorption, water retention, and an increase in blood pressure. Angiotensin II, in addition to being a potent vasoconstrictor, also causes an increase in ADH and increased thirst, both of which help to raise blood pressure. The action of aldosterone: ADH and aldosterone increase blood pressure and volume. Angiotensin II stimulates release of these hormones. Angiotensin II, in turn, is formed when renin cleaves angiotensin. This increases water retention and blood pressure.


The renin-angiotensin-aldosterone system increases blood volume and pressure
Renin
Angiotensin
Angiotensin I
Angiotensin II
Direct effects:
• Causes arteries to constrict resulting in an increase in blood pressure.
• Decreases glomerular filtration rate resulting in water retention.
• Increases thirst.
Triggers release of other hormones
Aldosterone
ADH
ADH is made in the hypothalamus and released by the posterior pituitary
Angiotensin is made by the liver
Aldosterone is produced by the adrenal glands, located on top of the kidneys.
Renin is produced by the kidney.
Causes nephron distal tubules to reabsorb more Na+ and water, which increases blood volume.
• Mediates insertion of aquaporins into nephron collecting duct cells. As a result, more water is reabsorbed into the blood.
• Causes arteries to constrict.

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CHAPTER-IV

ANIMAL AND REPRODUCTION

Neuro muscular co-ordination - types of neurons, transmissions of nerve impulse and reflex action. Chemical composition of muscle fiber and physiology of muscle contraction. Myoneural Junction. Endocrine glands in mammals. Physiology of mammalian reproduction - reproductive cycle - hormonal control of reproduction.

Mrs. P. KOUSALYA.,MSc.,M.Phil.

Assistant Professor,

PG and Research Department of Biochemistry,

Bharathidasan College of Arts and Science, Ellispettai,

Pallapalayam (PO), Erode-638116, Tamil Nadu, India.

E.mail: kousiviswa@gmail.com

NEURON

Neuron is the structural and functional unit of nervous system. It is a nerve cell. The nerve cells occur in brain, nerve cord, nerves, ganglia and autonomic nervous system. Neuron has three parts.

1. Cyton 2. Axon 3. Dendron or Dendrite

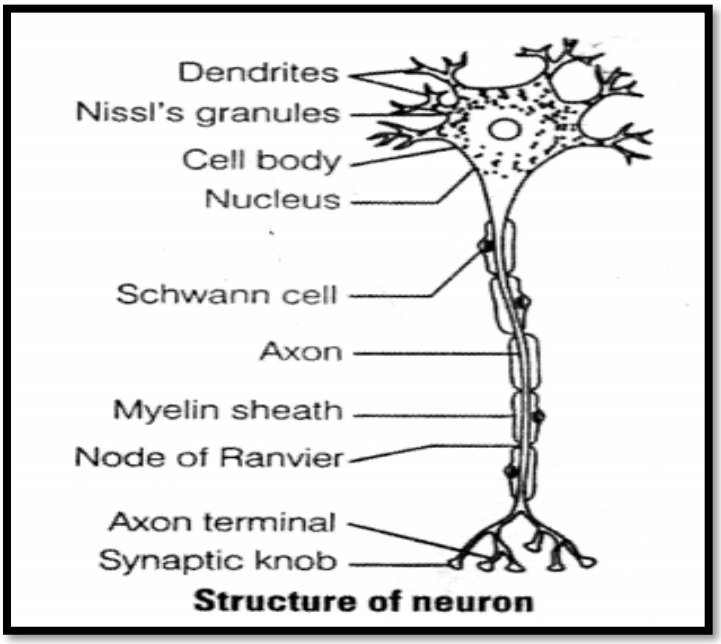


Figure -1:Structure of Neuron

CYTON

The part of neuron that looks like a cell called a cyton or soma or perikaryon. It is surrounded by a thin cell membrane called neurilemma. The cytoplasm of neuron is called as neuroplasm. The neuroplasm contains a prominent nucleus, fine filaments called as neurofibrils, basophilic granules called as Nissl granules, mitochondria,

golgicomplex and centriole. The Nissl's granules secrete the neuroplasm.

DENDRON

Dendrite or dendron is the process that carries impulse towards the cell body. It is generally short with many branches, and contains Nissl granules.

AXON

Axon is a long process. It is large in size. The cytoplasm of axon is axoplasm. The cytoplasm of axon is called as axoplasm. It is covered by a thin membrane called as axolemma. Nissil granules are absent. It carries impulse away from the cyton. The axon ends in branches called telodendria. The telodendria terminate in minute knobs called as boutons terminaux. The axon is surrounded by Schwann cells. In most neuron axon is coverd by myelin sheath or medullary sheath. The myelin sheath is constricted into segments at regular intervals. The point of constriction is called as node of ranvier. The part between two nodes is called internode. The internode is occupied by Schwann cells with a nucleus. The myelin sheath is secreted by Schwann cell. The myelin sheath is covered by a thin membrane called as neurilemma. It is the plasma

membrane of Schwann cell. An axon with its sheath is commonly called a nerve fibre. Nerve fibers join in bundles to form nerves. When myelin sheath is present, the nerve fiber is called a myelinated or medullated nerve fibre. When myelin sheath is absent the nerve fibre is called as non myelinated nerve fibre.

TYPES OF NEURONS

Neurons are commonly classified according to the number of their processes:

1. APOLAR NEURONS

Apolar neurons have no processes.

2. UNIPOLAR NEURON

Unipolar neuron have only one process the axon.

3. BIPOLAR NEURON

Typically these neurons are spindle-shaped possessing the axon at one end and a dendrite at the other end.

4. PSEUDOUNIPOLAR NEURONS

These types of neurons are at first typically bipolar and spindle-shaped, but as development proceeds the cell processes converge until these meet at one side of the cell

body. Then this elongates so that a fine process is formed with a T-shaped division at the end, one branch of the T being the dendrite from the periphery and the other being an axon extends centrally.

5. MULTIPOLAR NEURONS

These neurons have varied forms. A few of the common types are Purkinje cell of the cerebellar cortex, pyramidal cell of the motor cortex, small neuron from the spinal nucleus of the trigeminal nerve, motor neuron from the ventral horn of spinal cord, etc. Usually the shape depends mainly on the number and position of the dendrites.

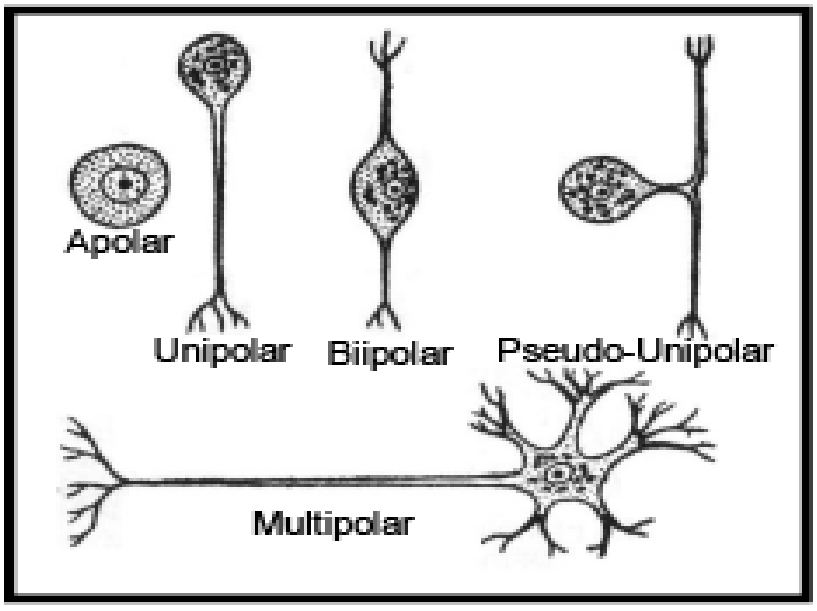


FIGURE-2: TYPES OF NEURON

TYPES OF NEURONS BASED ON FUNCTIONS

Neurons of the central nervous system is divided into following type based on the functions

1. Receptor neuron or sensory neuron
2. Effector neuron or motor neuron
3. Internuncial neurons

1. RECEPTOR NEURON OR SENSORY NEURON

These are bipolar or pseudounipolar nerve cells performing the reception and conduction of stimuli from peripheral receptors to the central nervous system.

2. EFFECTOR NEURON OR MOTOR NEURON

These neurons send impulses to the effector organs such as muscles and glands from the central nervous system.

3. INTERNUNCIAL NEURONS

These are placed between receptor and effector nerve cells. It provides communication between the receptor and effector cells.

HISTOLOGICAL CLASSIFICATION OF NEURON

Histologically neuron is classified into two types- Myelinated neuron and Non myelinted neuron

1. MYELINATED NEURON

This neuron contains medullary sheath on the axon. It is white in colour and it is called as white neuron.

2. NON MYELINATED NEURON

This neuron does not contain medullary sheath on the axon. It is grey in colour and it is called as grey neuron.

CLASSIFICATION BASED ON CHEMICAL SUBSTANCE RELEASE

On the basis of chemical substance released by the neurons, they are classified as –Adrenergic neurons and cholinergic neurons.

1. ADRENERGIC NEURONS

Adrenergic neurons release a hormone like substance called symphathin during impulse conduction. Symphathin is similar to adrenaline. Hence this neuron is called adrenergic Eg. Symphathetic nerves.

2. CHOLINERGIC NEURONS

These neurons produce acetyl choline during impulse conduction. Hence these neurons are called cholinergic. Eg. Parasymphathetic nerves and symphathetic nerves of sweat glands and uterus.

TRANSMISSION OF NERVE IMPULSE

Nerve impulse is defined as an electrochemical change occurring in the membrane of a nerve fibre when the nerve is stimulated. The nerve impulse is unidirectional in nerve fibres. The transmission of nerve impulse involves the active transport of Na+ and K+ ions across the membrane of nerve fiber. The junction between two neurons is called a synapse. Transmission of impulse across a synapse is called as synaptic transmission. The junction between a neuron and muscle is called as neuromuscular junction or myoneural junction. The conduction of impulse from motor neuron to muscles through neuromuscular junction is called as neuromuscular impulse transmission.

TYPES OF NERVE IMPULSE

There are 4 types of nerve impulse conduction

1. Conduction of impulse through non-myelinated neuron
2. Conduction of impulse through myelinated neuron
3. Conduction of impulse through synapse
4. Conduction of impulse through neuromuscular junction

CONDUCTION OF IMPULSE THROUGH NON-MYELINATED NEURON

A nerve fibre is in the form of along tube filed with axoplasm and is covered by a plasma membrane. The nerve impulse is conducted by sodium potassium pump. In the resting nerve fibre, the axoplasm is negatively charged and the outside (intercellular fluid) is positively charged. Membrane is more permeable to K+ than Na+ more K+ moves out and less Na+ move in. This is polarized state.The resting potential is about -70 milli volt.

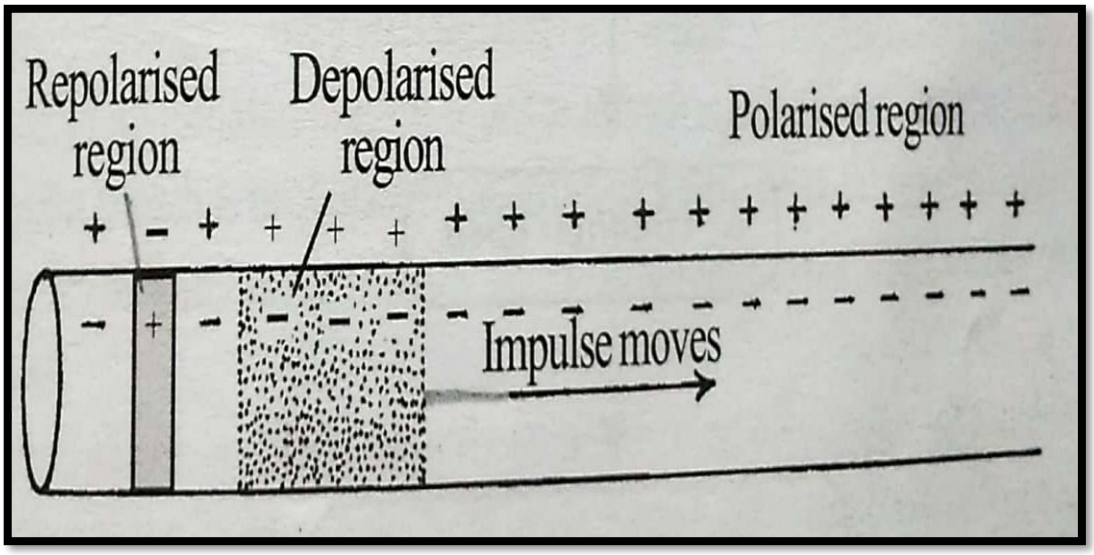


Figure-3: Conduction of nerve impulse

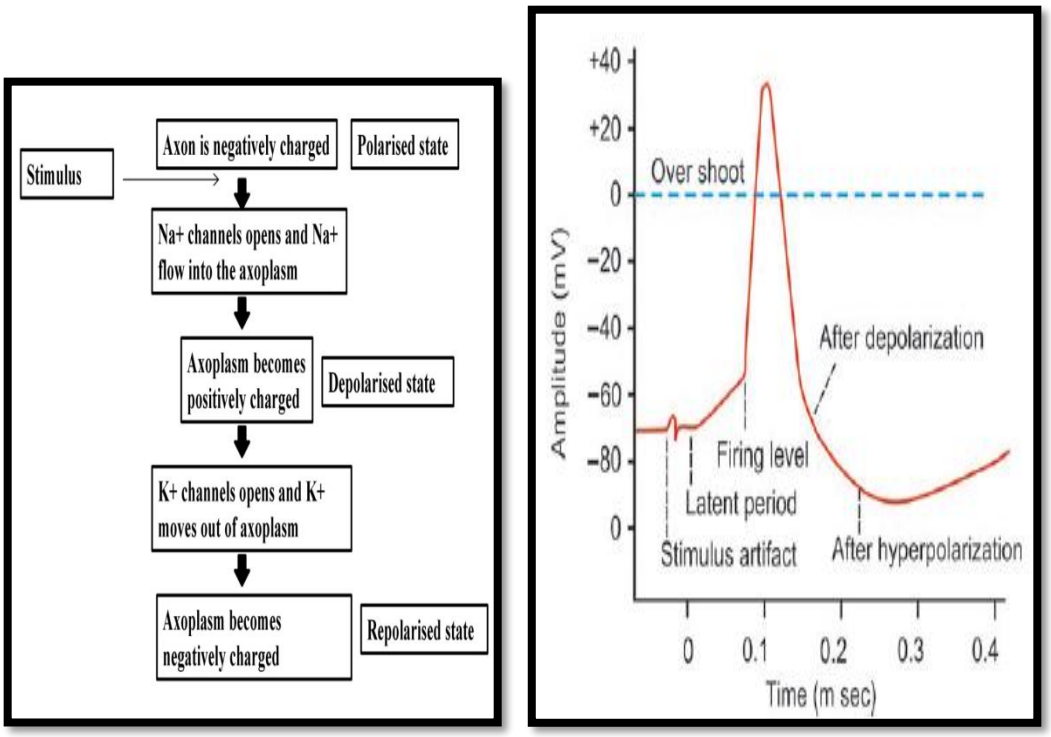


Figure-4: Conduction of nerve impulse, Action potential and Resting potential

In the excited axon axoplasm becomes positivey charged and intraceluar fluid becomes negatively charged. Membrane becomes more permeable to Na+ than to K+. More Na+ move in and less K+ pass out. This is the depolarisd state. The action potential is about +35 milli volt. Impulse moves bit by bit. As the impulse moves away, the region becomes repolarised. The region in front becomes depolarized.

MYONEURAL JUNCTION (OR) NEUROMUSCULAR JUNCTION

The junction between neuron and a muscle is called a neuromuscular junction or myoneural junction.The axon loses its myelin sheath and divides into many branches called axon terminals. Each terminal ends in a bulging called motor end plate. The motor end plate contains mitochondria and synaptic vesicles. The synaptic vesicle contains acetyl choline. The motor end plate comes in contact with muscle. At the point of contact the muscle has a depression called synaptic trough. There is a gap between motor end pate and the muscle called synaptic cleft. The membrane of motor end plate is called presynaptic membrane and the membrane of the muscle is called postsynaptic membrane. The postsynaptic membrane has folds called subneural clefts. The postsynaptic membrane contains receptors called acetylcholine receptors towards synaptic cleft.

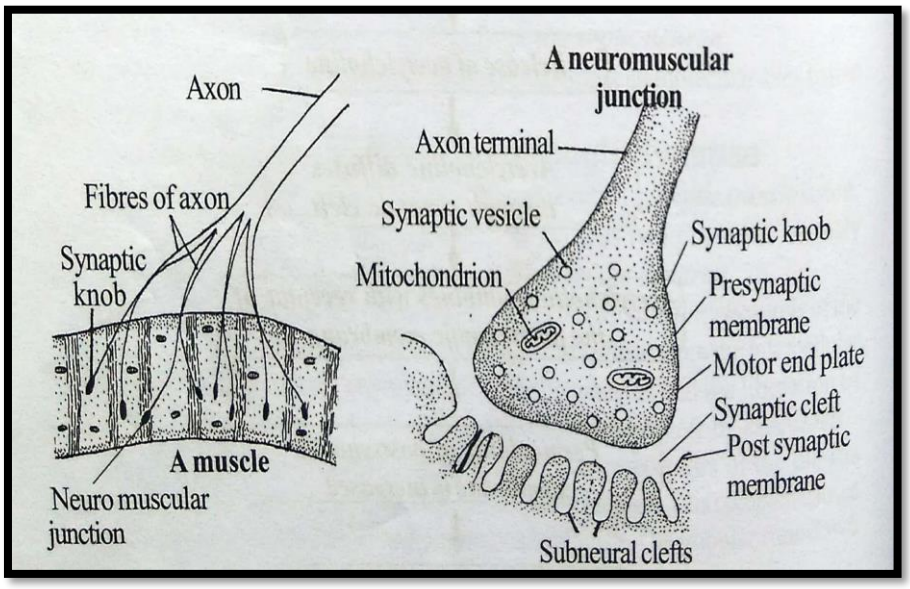


Figure-5: Neuromuscular Junction

NEUROMUSCULAR IMPULSE TRANSMISSION

The conduction of impulse from motor neuron to muscle through neuromuscular junction called as neuromuscular impulse transmission. The impulse reaches the motor end plate through the axon.

The calcium channels of the axolemma of motor end plate open. Calcium ions move into the axoplasm of motor end plate from the intercellular fluid. The calcium ions cause bursting of synaptic vesicles. The synaptic vesicles release acetylcholine. Acetyl choline enters the synaptic cleft through exocytosis. It binds with the acetylchoine receptor of postsynaptic membrane of muscle to form

acetyl choline-receptor complex. This opens sodium ion channels of the post synaptic membrane. Sodium ions are pumped into the sarcopalsm of muscles from the intercellular fluid. This cause the depolarization of sarcolemma.

The impulse produced in the sarcolemma is transmitted throughout the muscle fibre and cause muscle contraction. After the conduction of impuse in milli seconds, the acetyl choline is released from the receptor. In the synaptic cleft the acetylchoine is split by the enzyme choline esterase into acetic acid and choline. They diffuse into motor end plate and combine to form acetylcholine.

REFLEX ACTION

Reflex activity is the response to a peripheral nervous stimulation that occurs without our consciousness. It is a type of protective mechanism and it protects the body from irreparable damages. For example, when hand is placed on a hot object, it is withdrawn immediately. When a bright light is thrown into the eyes, eyelids are closed and pupil is constricted to prevent the damage of retina by entrance of excessive light into the eyes.

REFLEX ARC

Reflex arc is the anatomical nervous pathway for a reflex action. A simple reflex arc includes five components

1. RECEPTOR

Receptor is the end organ, which receives the stimulus. When receptor is stimulated, impulses are generated in afferent nerve.

2. AFFERENT NERVE

Afferent or sensory nerve transmits sensory impulses from the receptor to center.

3. CENTER

Center receives the sensory impulses via afferent nerve fibers and in turn, it generates appropriate motor impulses. Center is located in the brain or spinal cord.

4. EFFERENT NERVE

Efferent or motor nerve transmits motor impulses from the center to the effector organ.

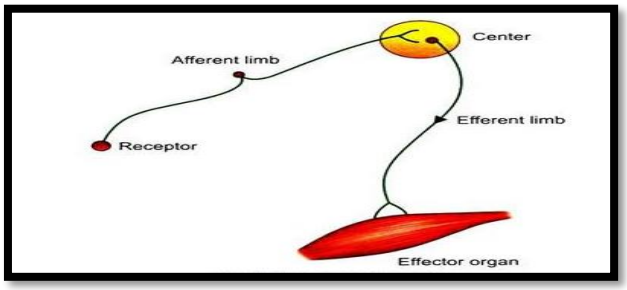


Figure-6: Reflex Arc

5. EFFECTOR ORGAN

Effector organ is the structure such as muscle or gland where the activity occurs in response to stimulus. Afferent and efferent nerve fibers may be connected directly to the center. In some places, one or more neurons are interposed between these nerve fibers and the center. Such neurons are called connector neurons or internuncial neurons or interneurons.

CLASSIFICATION OF REFLEXES

Reflexes is classified into the following types

1)DEPENDING UPON WHETHER INBORN OR ACQUIRED REFLEXES

This reflexes is further classified into 2 types

I.INBORN REFLEXES OR UNCONDITIONED REFLEXES

Unconditioned reflexes are the natural reflexes, which are present since the time of birth, hence the name inborn reflexes. Such reflexes do not require previous learning, training or conditioning. Best example is the secretion of saliva when a drop of honey is kept in the mouth of a newborn baby for the first time. The baby does not know the taste of honey, but still saliva is secreted.

II.ACQUIRED REFLEXES OR CONDITIONED REFLEXES

Conditioned or acquired reflexes are the reflexes that are developed after conditioning or training. These reflexes are not inborn but, acquired after birth. Such reflexes need previous learning, training or conditioning. Example is the secretion of saliva by sight, smell, thought or hearing of a known edible substance.

2) DEPENDING UPON THE NUMBER OF SYNAPSE

Depending upon the number of synapse in reflex arc, reflexes are classified into two types:

I. MONOSYNAPTIC REFLEXES

Reflexes having only one synapse in the reflex arc are called monosynaptic reflexes. Stretch reflex is the best example for monosynaptic reflex and it is elicited due to the stimulation of muscle spindle.

II. POLYSYNAPTIC REFLEXES

Reflexes having more than one synapse in the reflex arc are called polysynaptic reflexes. Flexor reflexes (withdrawal reflexes) are the polysynaptic reflexes.

3) DEPENDING UPON CLINICAL BASIS

Depending upon the clinical basis, reflexes are classified into two types:

I.SUPERFICIAL REFLEXES

Superficial reflexes are the reflexes, which are elicited from the surface of the body. Superficial reflexes are of two types: mucus membrane reflexes and skin reflexes.

II.DEEP REFLEXES

Deep reflexes are elicited from deeper structures beneath the skin like tendon. These reflexes are otherwise known as tendon reflexes.

STRUCTURE OF MUSCLE FIBER

Muscle tissue is made up of a large number of individual muscle cells or myocytes. The muscle cells are commonly called muscle fibers because these cells are long and slender in appearance. Each muscle cell or muscle fiber is cylindrical in shape. Average length of the fiber is 3 cm. The diameter of the muscle fiber varies from 10 μ to 100 μ. The diameter varies in a single muscle.

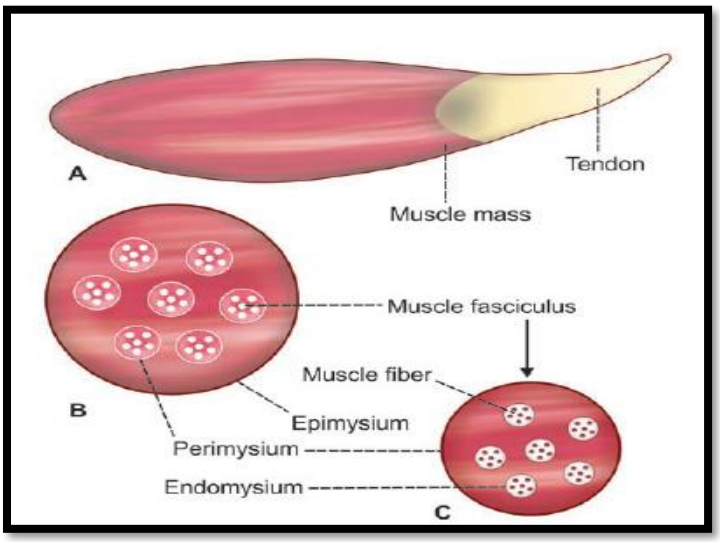


Figure-7: A-Skeletal muscle mass; B-Cross section of muscle; C-One muscle fasciculus

Muscle mass is separated from the neighboring tissues by a thick fibrous tissue layer known as fascia. Beneath the fascia, muscle is covered by a connective tissue sheath called epimysium. In the muscle, the muscle fibers are arranged in various groups called bundles or fasciculi. Connective tissue sheath that covers each fasciculus is called perimysium. Each muscle fiber is covered by a connective tissue layer called the endomysium. Muscle fibers are attached to a tough cord of connective tissue called tendon. Tendon is in turn attached to the bone.

Each muscle fiber is enclosed by a cell membrane called plasma membrane,that lies beneath the

endomysium. It is also called sarcolemma. Cytoplasm of the muscle is known as sarcoplasm.

Myofibrils or myofibrillae are the fine parallel filaments present in sarcoplasm of the muscle cell. Light microscopic studies show that, each myofibril consists of a number of two alternating bands which are also called the sections, segments or disks. These bands are formed by muscle proteins. The two bands are:

1. Light band or 'I' band.
2. Dark band or 'A' band.

I band is divided into two portions, by means of a narrow and dark line called 'Z' line or 'Z' disk. Sarcomere is defined as the structural and functional unit of a skeletal muscle. It is also called the basic contractile unit of the muscle. Each sarcomere extends between two 'Z' lines of myofibril. Thus, each myofibril contains many sarcomeres arranged in series throughout its length. When the muscle is in relaxed state, the average length of each sarcomere is 2 to 3 μ..

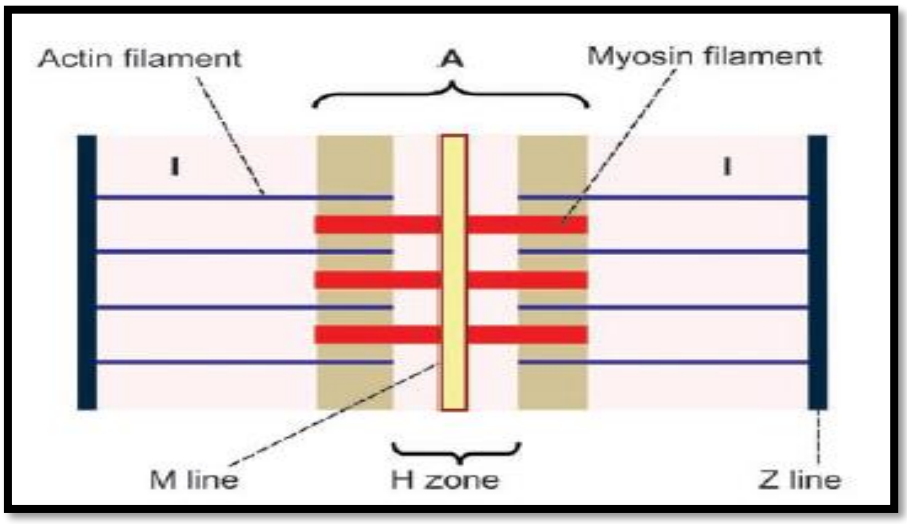


Figure-8:Sarcomere

Each myofibril consists of an alternate dark 'A' band and light 'I' band. In the middle of 'A' band, there is a light area called 'H' zone (H = hell = light – in German, H = Henson – discoverer). In the middle of 'H' zone lies the middle part of myosin filament. This is called 'M' line (in German-mittel = middle). 'M' line is formed by myosin binding proteins.

Electron microscopic studies reveal that the sarcomere consists of many thread like structures called myofilaments. Myofilaments are of two types: 1. Actin filaments 2. Myosin filaments.

ACTIN FILAMENTS

Actin filaments are the thin filaments with a diameter of 20 Å and a length of 1 μ. These filaments extend from either side of the 'Z' lines, run across 'I' band and enter into 'A' band up to 'H' zone. Actin molecules are the major constituents of the thin actin filaments. Each actin molecule is called F-actin and it is the polymer of a small protein known as G-actin. There are about 300 to 400 actin molecules in each actin filament. Each F-actin molecule has an active site to which the myosin head is attached. In relaxed condition of the muscle, the tropomyosin molecules cover all the active sites of F-actin molecules.

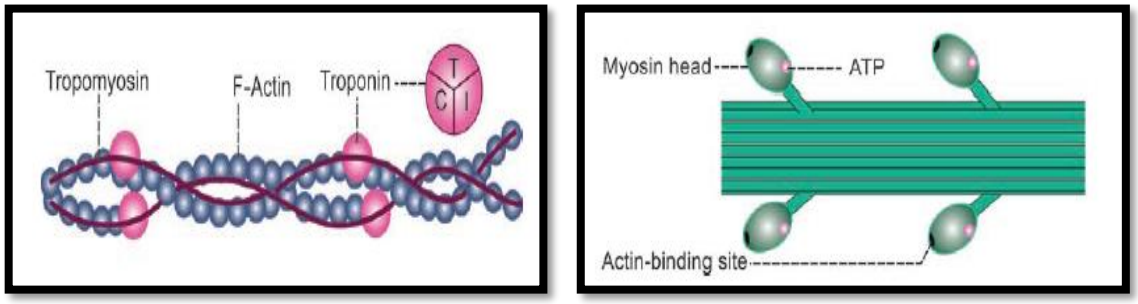


Figure-9: Part of Actin filament and Myosin filament

TROPONIN

It is formed by three subunits:

1. Troponin I, which is attached to F-actin.
2. Troponin T, which is attached to tropomyosin.

3. Troponin C, which is attached to calcium ions.

TROPOMYOSIN

About 40 to 60 tropomyosin molecules are situated along the double helix strand of actin filament.

MYOSIN FILAMENTS

Myosin filaments are thick filaments with a diameter of 115 Å and a length of 1.5 μ. These filaments are situated in 'A' band. Each myosin molecule has two portions- Tail portion and head. Each myosin head has two attachment sites. One site is for actin filament and the other one is for one ATP molecule.

CHEMICAL COMPOSITION OF SKELETAL MUSCLE:

The skeletal muscle contains about 75% water and 25% of solid matter. Skeletal muscle is formed by 75% of water and 25% of solids. Solids are 20% of proteins and 5% of organic substances other than proteins and inorganic substances. Muscle contains respiratory pigment called as myoglobin. Myoglobin is present in sarcoplasm. It is also called myohemoglobin. Its function is similar to that of

hemoglobin, that is, to carry oxygen. It is a conjugated protein.

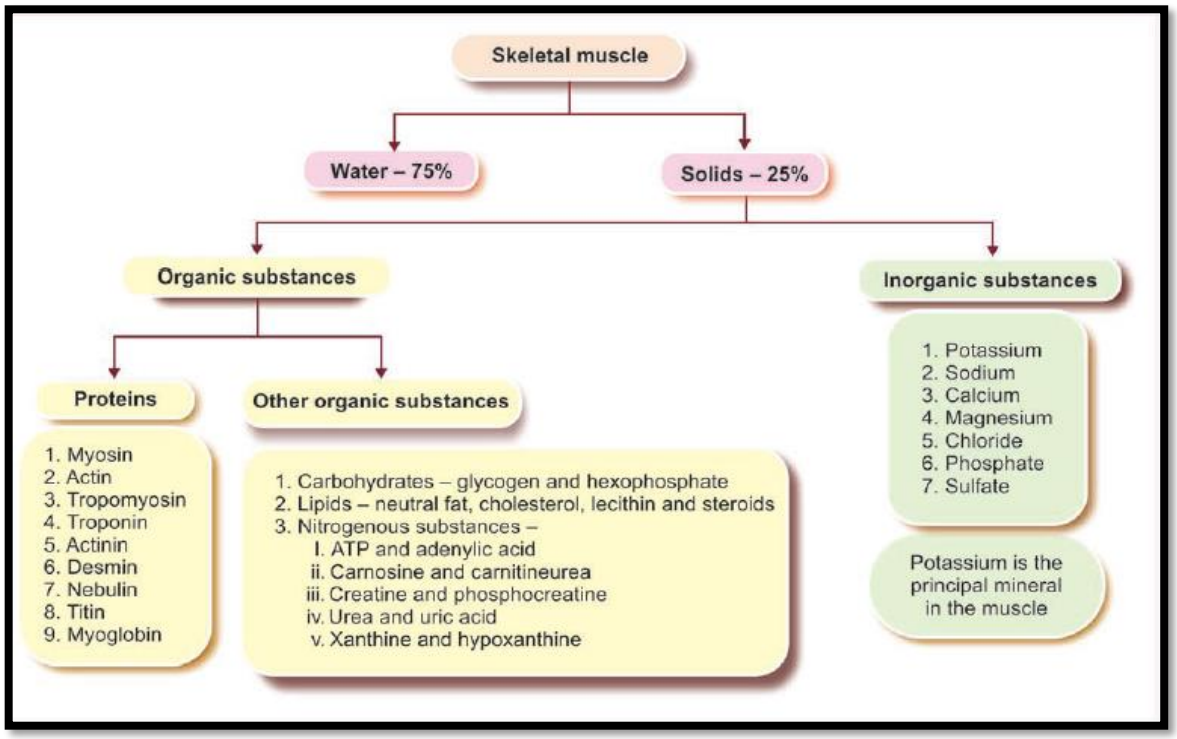


Figure-10: Composition of skeletal muscle

MUSCLE CONTRACTION

The process by which muscles are shortening is termed muscle contraction. Muscle contracts in response to various stimuli such as mechanical, electrical and thermal. There are two type of muscle contractions –Isometric and Isotonic contraction.

MECHANISM OF MUSCLE CONTRACTION

Sliding filament theory is proposed by Huxley and Hanson (1957).It is based on the structural changes occurring in the muscle fibers during contraction.

Each cross bridge from the myosin filaments has got three components namely, a hinge, an arm and a head. After binding with active site of F-actin, the myosin head is tilted towards the arm so that the actin filament is dragged along with it. This tilting of head is called power stroke. After tilting, the head immediately breaks away from the active site and returns to the original position. Now, it combines with a new active site on the actin molecule. And, tilting movement occurs again. Thus, the head of cross bridge bends back and forth and pulls the actin filament towards the center of sarcomere. In this way, all the actin filaments of both the ends of sarcomere are pulled. So, the actin filaments of opposite sides overlap and form actomyosin complex. Formation of actomyosin complex results in contraction of the muscle. When the muscle shortens further, the actin filaments from opposite ends of the sarcomere approach each other. So, the 'H' zone becomes narrow. And, the two 'Z' lines come closer with reduction in length of the sarcomere. However, the

length of ‘A’ band is not altered. But, the length of ‘I’ band decreases. When the muscular contraction becomes severe, the actin filaments from opposite ends overlap and the ‘H’ zone disappears.

CHANGES IN SARCOMERE DURING MUSCULAR CONTRACTION

Thus, changes that take place in sarcomere during muscular contraction are:

1. Length of all the sarcomeres decreases as the ‘Z’ lines come close to each other
2. Length of the ‘I’ band decreases since the actin filaments from opposite side overlap
3. ‘H’ zone either decreases or disappears
4. Length of ‘A’ band remains the same.

ENERGY FOR MUSCULAR CONTRACTION

Energy for movement of myosin head (power stroke) is obtained by breakdown of adenosine triphosphate (ATP) into adenosine diphosphate (ADP) and inorganic phosphate (Pi). Head of myosin has a site for ATP. Actually the head itself can act as the enzyme ATPase and

catalyze the breakdown of ATP. Even before the onset of contraction, an ATP molecule binds with myosin head. When tropomyosin moves to expose the active sites, the head is attached to the active site. Now ATPase cleaves ATP into ADP and Pi, which remains in head itself. The energy released during this process is utilized for contraction. When head is tilted, the ADP and Pi are released and a new ATP molecule binds with head. This process is repeated until the muscular contraction is completed.

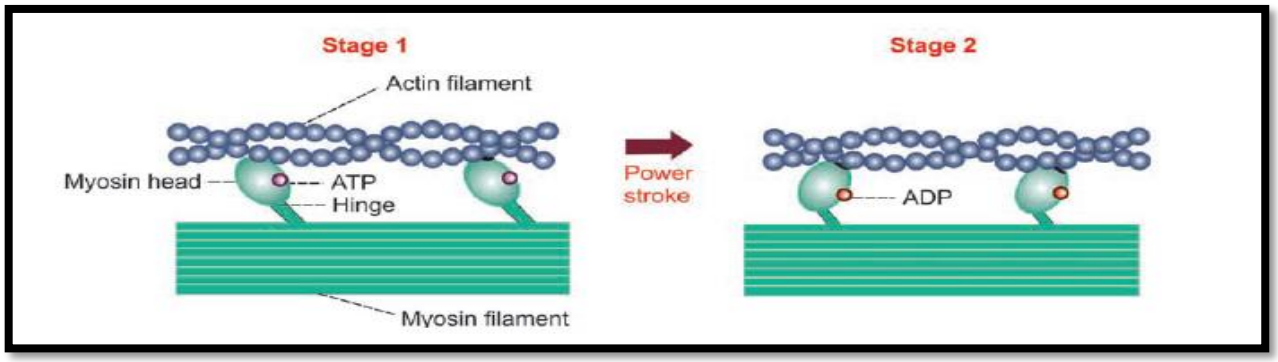


Figure-11: Stage1-Mysosin head binds with actin. Stage 2-Tilting of myosin head (power stroke) drags the actin filament.

ENDOCRINE GLANDS

All the physiological activities of the body are regulated by two major systems:

1. Nervous system
2. Endocrine system.

ENDOCRINE MESSENGERS

Endocrine messengers are the classical hormones. A hormone is defined as a chemical messenger, synthesized by endocrine glands and transported by blood to the target organs or tissues (site of action). Examples are growth hormone and insulin.

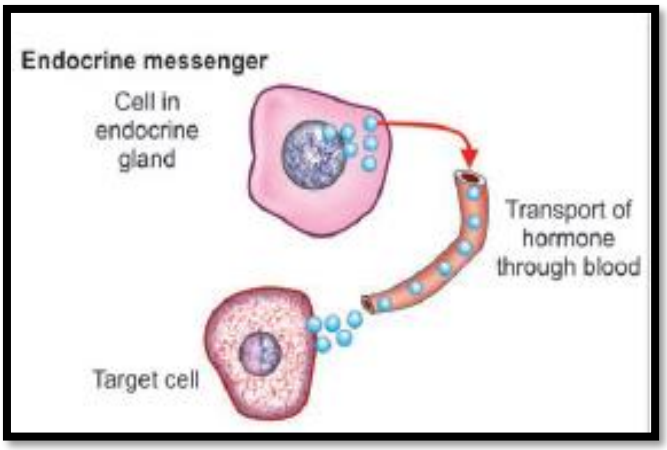


Figure-12:Endocrine messenger

Endocrine glands are the glands which synthesize and release the classical hormones into the blood. Endocrine glands are also called ductless glands because the hormones secreted by them are released directly into blood without any duct. Endocrine glands play an important role

in homeostasis and control of various other activities in the body through their hormones. Hormones are transported by blood to target organs or tissues in different parts of the body, where the actions are executed. Major endocrine glands are pituitary, thyroid, parathyroid, adrenal and pancreas.

PITUITARY GLAND

It is located in the brain just behind just behind optic chiasma. The average weight of pituitary is 05-0.6g in males and 0.6-0.7g in females. Pituitary contain two parts adenohypophysis or anterior lobe and neurohypophysis or posterior lobe. Anterior lobe secretes thyroid stimulating hormone (TSH), adrenocorticotropic hormone (ACTH), luetinizing hormone (LH), follicle stimulating hormone (FSH), growth hormone and prolactin. Posterior lobe secretes vasopressin and oxytocin.

HYPERPITUITARISM

Gigantism-It occurs from the hyperactivity of the gland. The growth of bone, legs and hands are high.

Acromegaly-The individual exhibits enlarged nose, hands, feet and thickening of the skin.

HYPORPITUITARISM

Dwarfism-The individual exhibit retarded growth.

THYROID GLAND

Thyroid glands Secretes thyroxine (T4) and tri-iodothyronine (T3). Generally 10-15 mg of iodine is in thyroid gland.

HYPOTHYROIDISM

Cretinism-Growth is retarded in children. The child is mentally defective.

Myxoedema-In adult it results in puffiness of face and hand.BMR is low.

HYPERTHYROIDISM

Toxic goiter –Affected individual is nervousness, restlessness and cannot tolerate warm climate.

Grave's Disease -Due to TSH, enlargement of thyroid is seen, uncontrolled production of T3 and T4, rapid heart rate and weight loss.

PARATHYROID GLAND

Parathyroid is a 4 small gland associated with thyroid.Parathyroid secretes parathormone

HYPOPRATHYROIDISM

Hyposecretion of parathormone results in muscular weakness, irritability, stunted growth in early childhood, serum and urine calcium is low, serum phosphate is increased.

HYPERPRATHYROIDISM

Hypersecretion of parathormone results in decalcification of bones, renal stones, serum phosphorus is low, serum alkaline phosphatase activity increased and excretion of calcium in urine is increased.

ADRENAL GLAND

There are two adrenal glands. Each gland is situated on the upper pole of each kidney. Because of the situation, adrenal glands are otherwise called suprarenal glands. Each gland weighs about 4 g.Adrenal gland consist of peripheral part called cortex and central part called as medulla. The hormones secreted by cortex are called as corticosteroids. They are glucocorticoids, mineralocorticoids and sex steroids. Adrenal medulla secretes two types of hormones which are chemically catecholamines. They are adrenalin and noradrenalin.

CUSHING'S SYNDROME

Hypersecretion of adrenal hormones results in cushing's Cushing's syndrome**.** It is a disorder characterized by high blood glucose levels and the accumulation of lipid deposits on the face and neck. It is caused by hypersecretion of cortisol. Other common signs of Cushing's disease include the development of a moon-shaped face, rapid weight gain, and hair loss.

ADDISON'S DISEASE

Hyposecretion of adrenal hormones results in Addison's disease. Addison's disease, a rare disorder that causes low blood glucose levels and low blood sodium levels. The signs and symptoms of Addison's disease include general weakness, abdominal pain, weight loss, nausea, vomiting, sweating, and cravings for salty food.

PANCREAS

Endocrine function of pancreas is performed by the islets of Langerhans. Human pancreas contains about 1 to 2 million islets. Islets of Langerhans consist of four types of cells:

1. A cells or α-cells, which secrete glucagon
2. B cells or β-cells, which secrete insulin
3. D cells or δ-cells, which secrete somatostatin

4. F cells or PP cells, which secrete pancreatic polypeptide.

INSULIN

Secreted by β-cells of islets of langerhans of pancreas.

FACTORS STIMULATING INULIN RELEASE

Increased blood glucose. Hyperglycemia by glucagon. Insulin facilitates transport of glucose and related monosaccharide in muscle and adipose tissue. Insulin promotes fatty acid synthesis in adipose tissue. In liver insulin stimulate glycolysis.

GLUCAGON

Secreted by α-cells of islets of langerhans of pancreas.

FACTORS STIMULATING GLUCAGON RELEASE

Reduced blood glucose stimulates glucagon release. Glucagon facilitates glycogenoysis, inhibits glycogen synthesis and stimulates gluconeogenesis. In adipose tissue and liver glucagon stimulates breakdown of lipids.

REPRODUCTIVE SYSTEM

Reproductive system ensures the continuation of species. Gonads are the primary reproductive organs which

produce the gametes (egg or ovum); a pair of testes (singular = testis) produces sperms in males and a pair of ovaries produces ovum in females.

MALE REPRODUCTIVE SYSTEM-TESTES

Testes are the primary sex organs or gonads in males. There are two testes in almost all the species. In human beings, both the testes are ovoid or walnut-shaped bodies that are located and suspended in a sac-like structure called scrotum. Each testis weighs about 15 to 19 g and measures about 5 × 3 cm. Testis is made up of about 900 coiled tubules known as seminiferous tubules, which produce sperms. Seminiferous tubules continue as the vas efferens, which form the epididymis. It is continued as vas deferens. Vas deferens is also called ductus deferens, spermatic deferens or sperm duct. From epididymis in scrotum, the vas deferens extends on its one side upwards into abdominal cavity via inguinal canal. Terminal portion of vas deferens is called ampulla. Ampulla of vas deferens joins ducts of seminal vesicle of same side, to form ejaculatory duct. Thus, there are two ejaculatory ducts each of which receives sperm from vas deferens and secretions of seminal vesicle on its own side. Both the ejaculatory

ducts empty into a single urethra. Actually, ejaculatory ducts open into prostatic part of urethra. Seminal vesicles are the paired glands situated in lower abdomen on either side of prostate gland behind urinary bladder. Human prostate gland weighs about 40 g. It consists of 20 to 30 separate glands, which open separately into the urethra.

Each testis is enclosed by three coverings.

1. TUNICA VASCULOSA

Tunica vasculosa is the innermost covering. It is made up of connective tissue and it is rich in blood vessels.

2. TUNICA ALBUGINEA

Tunica albuginea is the middle covering. It is a dense fibrous capsule.

3. TUNICA VAGINALIS

Tunica vaginalis is the outermost closed cleft like covering, formed by mesothelial cells.

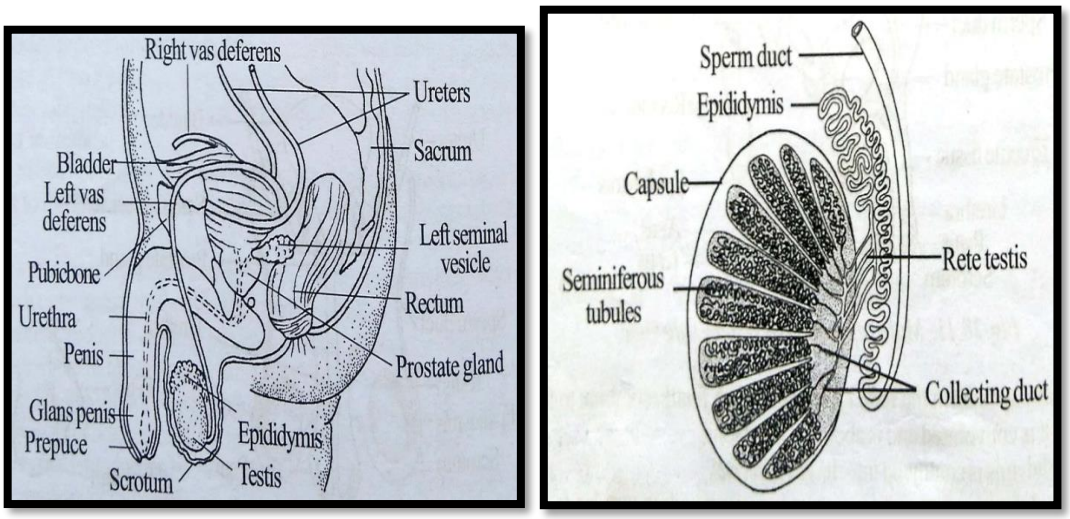


Figure-13: Male Reproductive System and seminiferous tubulesLOBULES OF TESTES

Each testis has about 200 to 300 lobules.

SEMINIFEROUS TUBULES

Each lobule contains 1 to 4 coiled tubules known as the seminiferous tubules, which are surrounded and supported by interlobular connective tissue.

RETE TESTIS

Rete testis is a network of thin-walled channels present in mediastinum. All the seminiferous tubules open into the rete testis.

VAS EFFERENS

From rete testis, 8 to 15 tubules called vas efferens arise. Vas efferens join together and form the head of

epididymis and then converge to form the duct of epididymis.

EPIDIDYMIS

Duct of epididymis is an enormously convoluted tubule, with a length of about 4 meter. It begins at head, where it receives vas efferens.

VAS DEFERENS

Epididymis turns sharply upon itself and continues as vas deferens, without any definite demarcation.

INTERSTITIAL CELLS OF LEYDIG

Interstitial cells of Leydig are the hormone secreting cells of testis, lying in between the seminiferous tubules.

SEMINIFEROUS TUBULES

Seminiferous tubules are thread-like convoluted tubular structures which produce the spermatozoa or sperms. There are about 400 to 600 seminiferous tubules in each testis. Each tubule is 30 to 70 cm long with a diameter of 150 to 300 μ. Wall of the seminiferous tubule is formed by three layers:

1. Outer capsule or tunica propria, formed by fibroelastic connective tissue
2. Thin homogeneous basement membrane

3. Complex stratified epithelium, which consists of two types of cells. Spermatogenic cells or germ cells and sertoli cells or supporting cells.

SPERMATOGENIC CELLS OR GERM CELLS

Spermatogenic cells or germ cells present in seminiferous tubules are precursor cells of spermatozoa. These cells lie in between sertoli cells and are arranged in an orderly manner in 4 to 8 layers. In children, the testis is not fully developed. Therefore, the spermatogenic cells are in primitive stage called spermatogonia. With the onset of puberty, spermatogonia develop into sperms through different stages.

STAGES OF SPERMATOGENIC CELLS

Different stages of spermatogenic cells seen from periphery to the lumen of seminiferous tubules are:

1. Spermatogonium
2. Primary spermatocyte
3. Secondary spermatocyte
4. Spermatid.

SERTOLI CELLS OR SUPPORTING

Sertoli cells are the supporting cells for spermatogenic cells in seminiferous tubules. These cells are also called sustentacular cells or nurse cells. Sertoli cells are the large and tall irregular columnar cells, extending from basement membrane to lumen of the seminiferous tubule. Germ cells present in seminiferous tubule are attached to sertoli cells by means of cytoplasmic connection. This attachment between germ cells and sertoli cells exists till the matured spermatozoa are released into the lumen of seminiferous tubules.

FUNCTIONS OF SERTOLI CELLS

Sertoli cells provide support, protection and nourishment for the spermatogenic cells present in seminiferous tubules.

FUNCTIONS OF TESTES

1. Gametogenic function: Spermatogenesis
2. Endocrine function: Secretion of hormones.

SPERMATOGENESIS

Spermatogenesis is the process by which the male gametes called spermatozoa (sperms) are formed from the primitive spermatogenic cells (spermatogonia) in the testis.

It takes 74 days for the formation of sperm from a primitive germ cell. Throughout the process of spermatogenesis, the spermatogenic cells have cytoplasmic attachment with sertoli cells. Sertoli cells supply all the necessary materials for spermatogenesis through the cytoplasmic attachment.

STAGES OF SPERMATOGENESIS

Spermatogenesis occurs in four stages:

1. Stage of proliferation
2. Stage of growth
3. Stage of maturation
4. Stage of transformation.

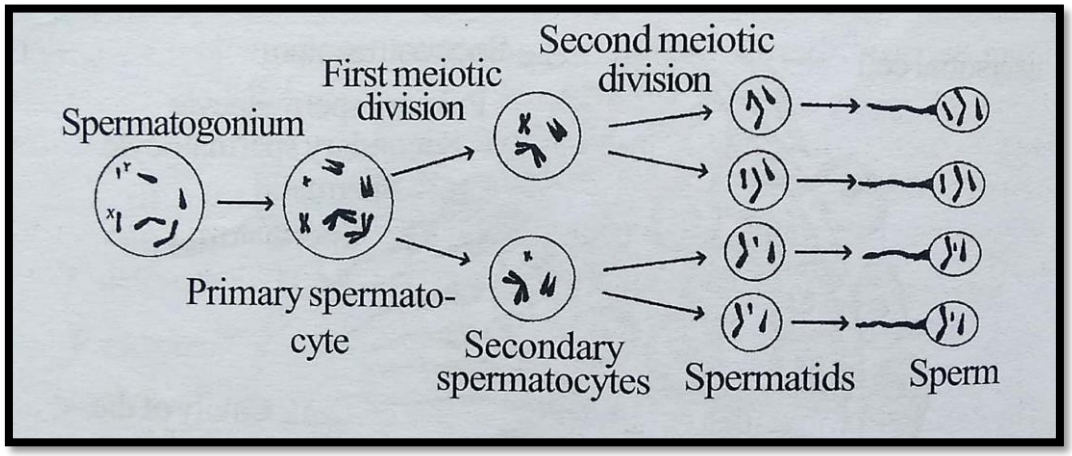


Figure-14:Spermatogenesis

1. STAGE OF PROLIFERATION

Each spermatogonium contains diploid number (23 pairs) of chromosomes. One member of each pair is from

maternal origin and the other one from paternal origin. The 23 pairs include 22 pairs of autosomal chromosomes and one pair of sex chromosomes. Sex chromosomes are one X chromosome and one Y chromosome. During the proliferative stage, spermatogonia divide by mitosis, without any change in chromosomal number. In man, there are usually seven generations of spermatogonia. The last generation enters the stage of growth as primary spermatocyte. During this stage, the spermatogonia migrate along with sertoli cells towards the lumen of seminiferous tubule.

2. STAGE OF GROWTH

In this stage, the primary spermatocyte grows into a large cell. Apart from growth, there is no other change in spermatocyte during this stage.

3. STAGE OF MATURATION

After reaching the full size, each primary spermatocyte quickly undergoes meiotic or maturation division, which occurs in two phases.

In the first phase, each primary spermatocyte divides into two secondary spermatocytes. The significance of the first meiotic division is that each secondary spermatocyte

receives only the haploid or half the number of chromosomes. 23 chromosomes include 22 autosomes and a X or a Y chromosome.

During the second phase, each secondary spermatocyte undergoes second meiotic division, resulting in two smaller cells called spermatids. Each spermatid has haploid number of chromosomes.

4. STAGE OF TRANSFORMATION

There is no further division. Spermatids are transformed into matured spermatozoa (sperms), by means of spermeogenesis and released by spermination.

HORMONES SECRETED BY TESTIS

Testes secrete male sex hormones, which are collectively called the androgens. Androgens secreted by testes are testosterone, dihydrotestosterone and androstenedione. Among these three androgens, testosterone is secreted in large quantities. However, dihydrotestosterone is more active.

FEMALE REPRODUCTIVE SYSTEM

Female reproductive system consists of a pair of ovaries, a pair of fallopian tubes, oviducts, the uterus and the vagina. The ovary is attached to the dorsal body all

through a connective tissue membrane called mesovarium. The fallopian tube is the oviduct. One end of the fallopian tube has a funnel like opening near the ovary called infundibulum. It opens into pelvic cavity near the ovary. The margin of the infundibulum contains many fimbriae. One fimbria is attached to the ovary. This fimbria is called ovrian fimbria. The other end of the fallopian tube opens into the uterus. The uterus has two regions, namely upper body and a lower cervix. The cervix leads into vagina. The cavity enclosed by the body of uterus is called uterine cavity and that of the cervix is called cervical canal. The inner most layer of the uterus is called as endometrium. It is formed of epithelial cells and tubular coiled gland.

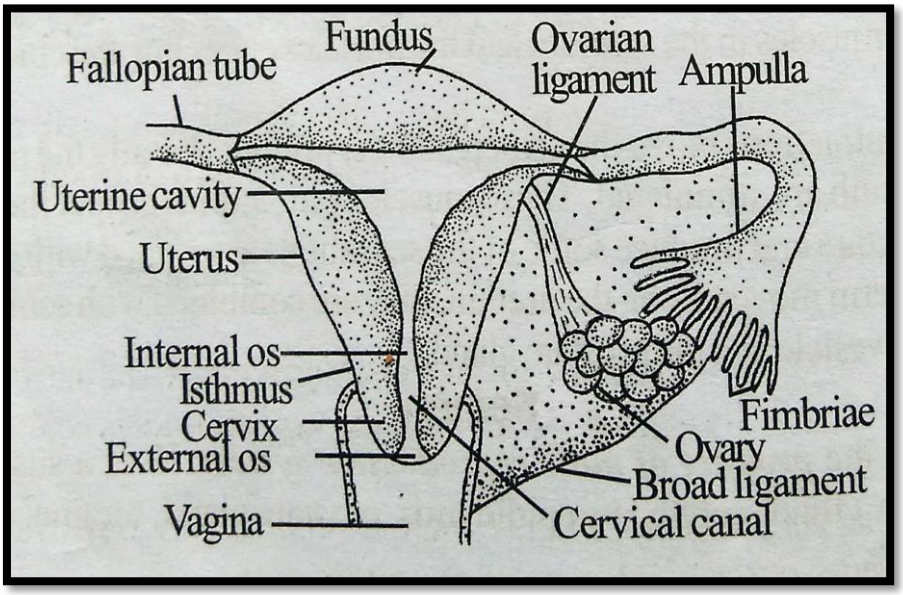


Figure-15:Female Reproductive System

OVARY

In female, ovary functions as an egg producing organ as well as endocrine gland. The ovary is covered by a single layer of epithelial cells called as germinal epithelium.It is the parent tissue from which graffian follicle develop. Beneath this layer, there is a thin layer called tunica albuginea. The interior of ovary is formed of stroma. It is formed by the continuation of the mesovarium into the ovary. The stroma contains groups of secretory cells called interstitial cells. They secrete estrogen. The peripheral region of ovary contains numerous islands of cells called graffian follicles. The ruptured follicles are called as corpus haemorrhagicum, corpus luteum and corpus albicans.

OOGENESIS

Oogenesis refers to the process of formation of ova from the primitive germ cells.

PRIMITIVE GERM CELLS

When the bipotential gonads differentiate into ovaries in genetic female (44 + XX) embryo by 10th week of gestation, the primitive germ cells increase in number by

mitosis to form oogonia. Oogonia are the stem cells from which ova are derived. The oogonia proliferate by mitosis to form primary oocytes. Primary oocytes, formed from the oogonia, enter a prolonged prophase (diplotene stage) of the first meiotic division and remain in this state until ovulation occurs after puberty.

PRIMORDIAL FOLLICLES

The diploid primary oocytes become enveloped by a single layer of flat granulosa cells and in this form are called primordial follicles. After puberty, the oogenesis or formation of ovum occurs in a highly cyclic fashion, once every 28 days till menopause. Every month, in each ovary, more than one primordial follicles start undergoing maturation process, but only one reaches maturity and the rest undergo atresia at different stages of development. The different stages of maturation of primordial follicle into graafian follicle (folliculogenesis).

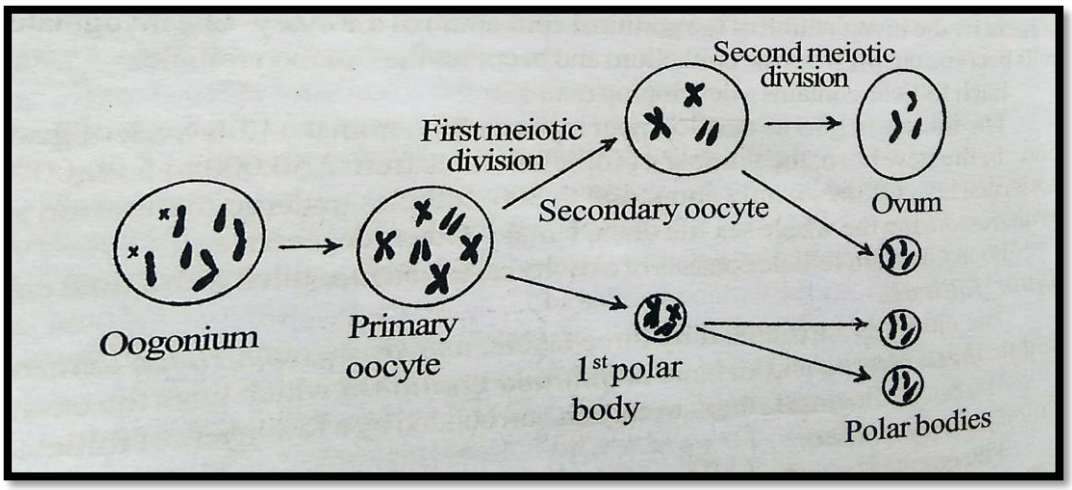


Figure-16: Oogenesis

ENDOCRINE FUNCTION OF OVARIES

The endocrine function of the ovaries is to produce female sex hormones which include-Oestrogens and Progesterone.

OESTROGENS

Oestrogens are (C-18) steroids. The naturally occurring oestrogens include- Oestradiol, oestrone and oestriol.

Oestradiol is the principal and physiologically most potent oestrogen. Ovarian oestradiol accounts for more than 90% of the circulating oestrogens. Oestrone is a weak ovarian oestrogen. Oestriol is the degradation product of oestradiol and oestrone. It is the weakest of all naturally occurring oestrogens.

PROGESTERONE

Progesterone is C-21 steroid meant for maintenance of pregnancy and is biologically called prostagen or gestagen.

MENSTURAL CYCLE

The rhythmic change undergone by the sexual organ at an interval of 28 days is called as menstrual cycle. Mensturation is the periodic discharge of blood, mucus and cellular debris from the uterus trough vagina at about 28 days (four weeks). The endometrial cycle of 28 days can be divided into three

Phases

1. Menstrual phase (1st–5th day),
2. Proliferative phase (6th–14th day) and
3. Secretory phase (15th–28th day).

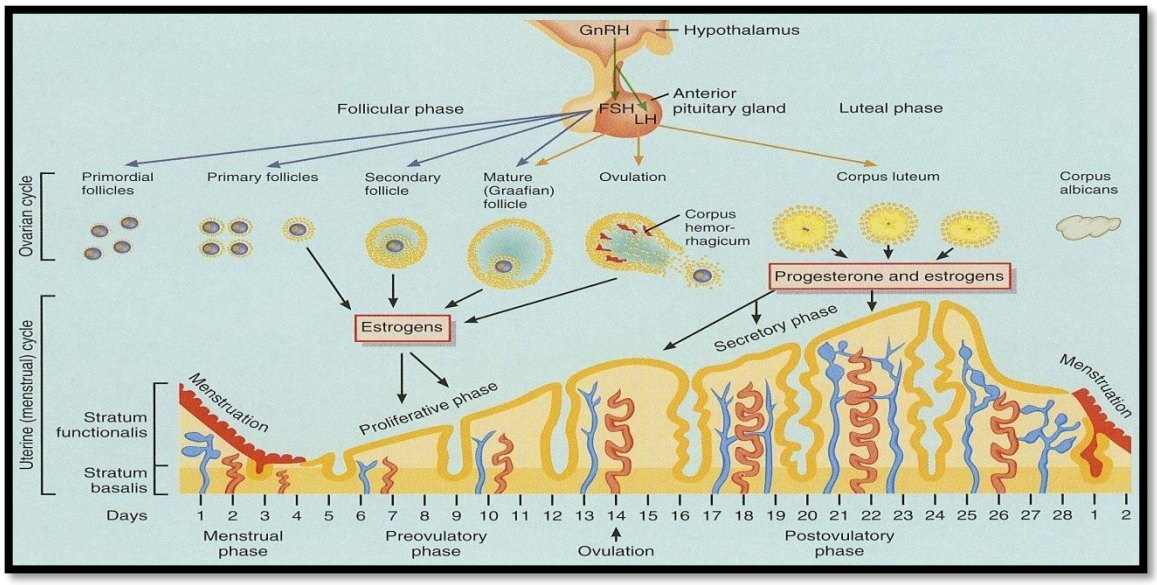


Figure-17: Menstural cycle

PROLIFERATIVE PHASE

Extent of proliferative phase of is from day 6th to 14th day. It follows the phase of menstruation, after which only a thin basal layer of original endometrium is left. Hormone responsible for the changes in the endometrium during this phase is oestrogen secreted by the developing graafian follicle in the ovary. Thus, proliferative phase of the endometrial cycle coincides with the follicular phase of ovarian cycle. Changes in endometrium which occur during proliferative phase are: (i) Thickness of endometrium, which is less than 1 mm at the end of menstrual phase increases to 3–4 mm at the end of the proliferative phase. (ii)Angiogenesis in the stratum

functionale leads to proliferation of blood vessels. (iii)Endometrial glands are stimulated to grow.

SECRETORY PHASE

Extent of secretory phase (also known as post-ovulatory phase of endometrial cycle) is from day 15th–28th day. Hormones responsible for changes in the endometrium during this phase are both oestrogen and progesterone secreted by the corpus luteum formed after ovulation. Thus, the secretory phase of endometrial cycle coincides with the luteal phase of ovarian cycle. Changes in the endometrium which occur during this phase are: (i)There is elongation and coiling of the endometrial mucous glands. These glands become secretory and secrete thick viscous fluid containing glycogen. Blood supply of endometrium further increases as progesterone promotes spiralling of blood vessels. (ii)Thickness of endometrium increases to 5–6 mm at the end of secretory phase. Thus the thickened endometrium with large amounts of nutrients is ready to provide appropriate conditions for implantation of ovum during this phase. (iii) If fertilization does not occur and there is no pregnancy, the corpus luteum in the

ovary involutes to form corpus albicans, and on day 26th of the menstrual cycle the levels of oestrogen and progesterone fall suddenly and mark the end of secretory phase of endometrial cycle.

MENSTRUAL PHASE

The menstrual phase of endometrial cycle is also called bleeding phase. The average duration of this phase is 3–5 days. About 24 hours before the end of menstrual cycle, there is sharp decline in the plasma levels of oestrogen and progesterone, which are responsible for menstrual bleeding. Endometrial debris contains necrosed, sloughed-tissue, blood, serous fluid and large amounts of prostaglandins and fibrolysins. Menstrual blood immediately gets clotted inside the uterine cavity but soon gets liquefied by fibrolysins present in the endometrial debris. During menstrual phase, about two-thirds of the superficial endometrium is sloughed off and only a thin basal layer (2 mm thick) is left behind.

PREGNANCY

In mammals,fertilization of ovum takes place in the upper part of fallopian tube. Cleavage begins at once to form blastocyst .The blastocyst, then reaches the uterus, is implanted in uterine wall. The attachment is facilitated by placenta, a structure formed by the maternal and foetal tissues. When pregnancy begins, the menstruation and ovulation are prevented till birth.

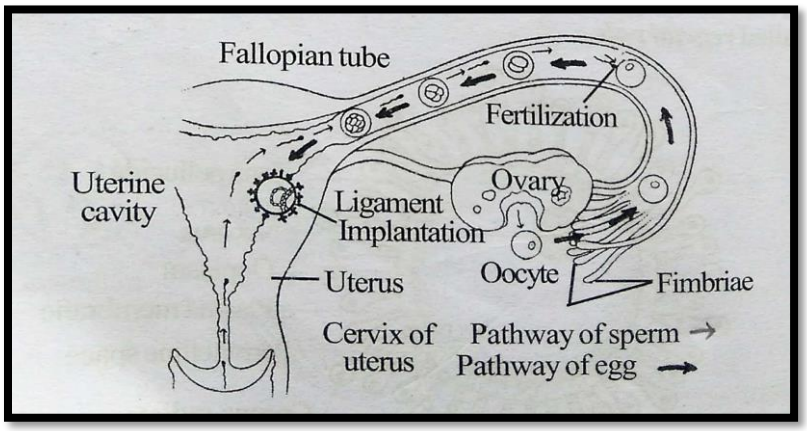


Figure-18: Fertiization and implantation of fertilized egg

HORMONAL REGULATION OF MALE REPRODUCTIVE CYCLE

The spermatogenesis is controlled by following negative feedback mechanisms .Inhibin secreted by the sertoli cells acts directly on the anterior pituitary and inhibits the secretion of FSH. Testosterone and oestradiol inhibit LH secretion by negative feedback mechanism:

Oestradiol exerts the negative feedback effect at both the hypothalamic (GnRH) and pituitary (LH) levels. **Testosterone** has its feedback effect mainly at the hypothalamic (GnRH) level.

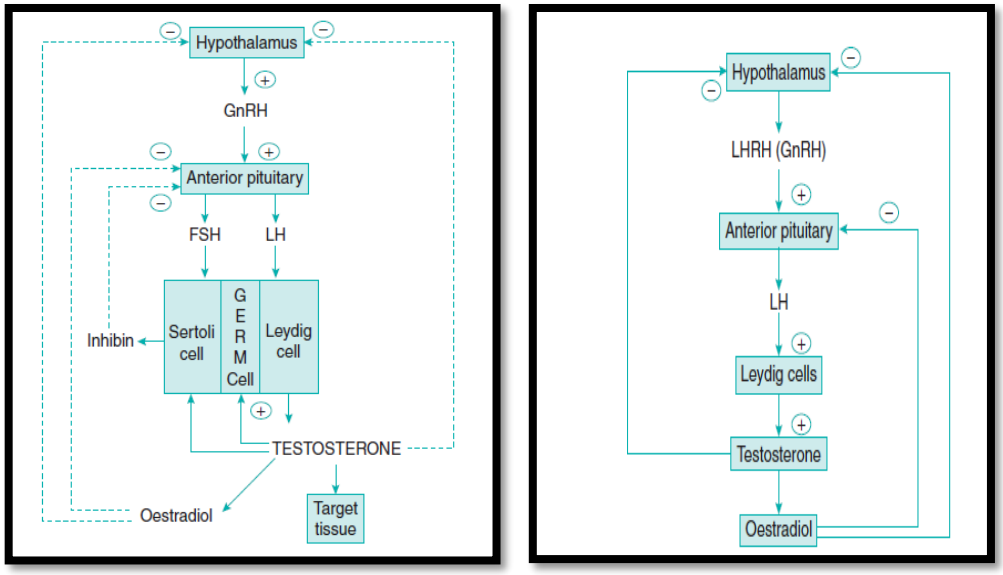


Figure-19:Stimulatory and feedback control of spermatogenesis and testosterone

FEEDBACK INHIBITORY CONTROL OF TESTOSTERONE

Plasma testosterone level is maintained at a constant level by a feedback control exerted by testosterone and oestradiol independently to control LH

HORMONAL REGULATION OF FEMALE REPRODUCTIVE CYCLE

ROLE OF HYPOTHALAMUS

Hypothalamus regulates the secretions of gonadotropins (both FSH and LH) through the gonadotropin-releasing hormone (GnRH). The gonadotropin-releasing hormone (GnRH) is also known as luteinizing hormone-releasing hormone (LHRH). It reaches the anterior pituitary through hypothalamo–hypophyseal portal system, where it is stored as small granules. It stimulates the anterior pituitary cells to release gonadotropins.

ROLE OF ANTERIOR PITUITARY

The anterior pituitary plays its role in the female sexual cycle regulation by releasing gonadotropins (FSH and LH). Gonadotropins in turn regulate the ovarian cycle, i.e. formation of graafian follicles (folliculosis), ovulation and formation of corpus luteum.

REGULATION OF GONADOTROPINS

The secretion of both FSH and LH is regulated by the following.

1. Gonadal hormones - The gonadal hormones (oestrogen and progesterone) regulate gonadotropin secretion by their feedback effect. High levels of oestrogen and progesterone in mid-luteal phase inhibit the secretion of FSH and LH (by negative feedback effect). Low levels of gonadal hormones (during menstruation phase) increase the secretion of both FSH and LH (by positive feedback effect).The feedback effect (positive or negative) of ovarian hormones is brought about by its action either directly on anterior pituitary or through the hypothalamus.

2. Human chorionic gonadotropin (HCG). It is a glycoprotein secreted by syncytiotrophoblasts during early pregnancy (12–16 weeks of gestation). Like LH, HCG also maintains the functional state of corpus luteum, and thus elevates gonadal hormones resulting in inhibition of gonadotropin release.

3. Prolactin. It is a mammotropic hormone secreted from anterior pituitary during lactation. It inhibits GnRH release and thus lowers the basal secretion of FSH and LH (cause for lactation amenorrhoea).

4. Activin. It is structurally quite similar to inhibin (secreted from ovary). It is synthesized in the cells of the anterior pituitary. It stimulates the synthesis and release of FSH by autocrine and paracrine actions.

ROLE OF OVARIES

Ovaries play an important role in the regulation of ovarian cycle and endometrial cycle by secreting gonadal hormones (oestrogen and progesterone).

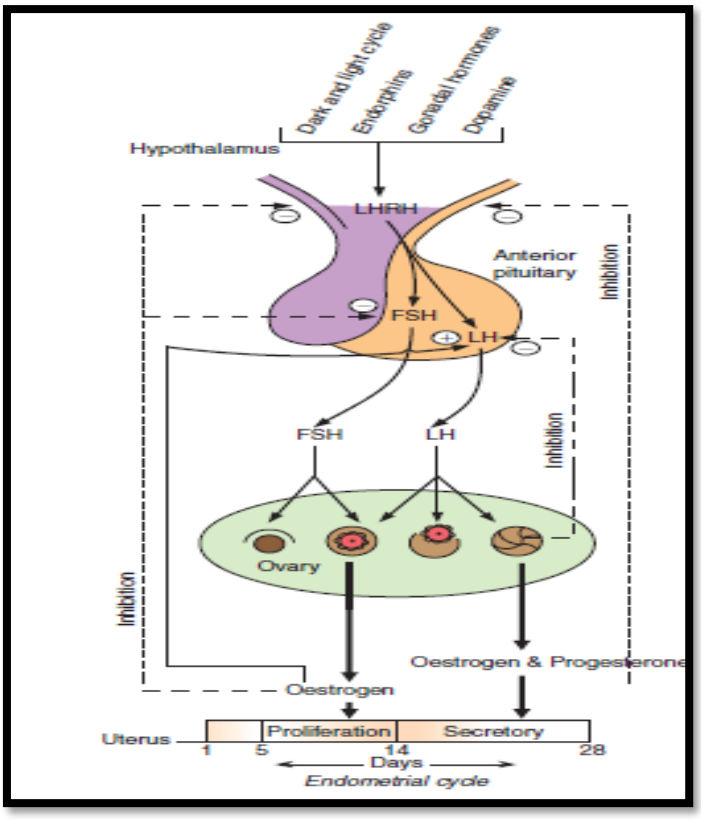


Figure-20: Hormonal control of female reproduction.

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CHAPTER V

(BEHAVIOURAL PHYSIOLOGY)

Bioluminescence - chemistry and functional significance. Behaviour (types - trophism, taxis, kinesis, reflex, learning). Temperature regulation: Poikilotherms, homeotherms and heterotherms - hibernation, aestivation - diapause.

Dr. G. Abi Beaulah, M.Sc., M.Phil., SET., Ph.D

Head & Assistant Professor,

Department of Biochemistry

Auxilium College (Autonomous),

Gandhi Nagar, Vellore, Tamil Nadu, India

BIOLUMINESCENCE

Bioluminescence is the production and emission of light by a living organism, for its survival and propagation. It is a form of chemiluminescence. Bioluminescence occurs widely in marine vertebrates and invertebrates. Also, it occurs in some fungi, bacteria, and terrestrial arthropods such as fireflies. Bioluminescence on land and in freshwater is rare compared to its occurrence in the ocean. Bioluminescence is higher in deep-living and planktonic organisms. In the deep ocean 90% of the animals are luminescent. Sunlight is dim or absent in deep ocean. So, bioluminescence is effective in vast allowing natural selection. In some animals, the light is bacteriogenic, produced by symbiotic bacteria such as those from the genus *Vibrio*; in others, it is autogenic, produced by the animals themselves. Bioluminescence is referred as Cold light because less than 20% of the light generates thermal radiation, or heat.

DEFINITION:

Bioluminescence is the production and emission of light by a living organism, for its survival and propagation.

ORIGIN OF NOMENCLATURE

The insect genus: Pyrophorus, from Greek pyro fire; phero to bear.

Phosphor: from Greek phos light; phosphoros the morning star.

Lucifer: light bearing, Latin lux, lucis light; lucifer the morning Star.

Luciferase and luciferin are generic terms used today.

HISTORY:

Bioluminescence is one of the oldest fields of scientific study, dating from the first written records of the ancient Greeks. Written reports remained fragmentary till the time of Aristotle (384-322 BCE), who was the first to recognize the self-luminosity of organisms and that it was not accompanied by heat. Aristotle wrote about the glow from dead fish or flesh now known to be from an infection by bioluminescent bacteria, and the light generated on disturbance of sea-water, and of fireflies and glow-worms. The specific and complete record of bioluminescent organisms, was by Pliny the Elder (23-79 CE). In his Naturalis Historia, there are quite detailed descriptions of many bioluminescent animals: the glow worm and

fireflies, the luminous mollusc (Pholas dactylus) (a Roman delicasy), the purple jellyfish (Pelagia noctiluca) still common in the Mediterranean, the lantern fish, luminous mushrooms, and glowing wood. Pliny also wrote that there were reports of luminous birds in the Black Forest of Germany but added that this was just hearsay and unfounded rumour. Nevertheless, the belief that such bioluminescent birds existed, continued for more than a thousand years showing the persistence of unsubstantiated rumour without independent verification. The first scientist to define Bioluminescence was Cormier and Totter in 1968. They defined Bioluminescence as the emission of light as a consequence of cellular oxidation of some substrates in the presence of an enzyme.

In the region of the Sengalor River in Malaysia, tourist have encountered the “Firefly Christmas Tree”. Hundreds of fireflies may settle on a tree and flash in synchrony, all blinking on, then going dark over a several seconds time period. It is as if their blinking is governed by a single controller. The same is also seen in the Great Smoky Mountains National Park in the Eastern USA. This phenomenon is an impressive instance of "Living Light".

BIOLUMINESCENT ORGANISMS

Around 17 phyla and at least 700 genera contain luminous species. Many marine organisms show bioluminescence wherein the colour that is emanated is usually green, blue and rarely red colour. Apart from marine organisms, bioluminescence is also observed in the land organisms, precisely invertebrates such as fireflies, worms, larvae – insects.

Examples of organisms that can exhibit bioluminescence.

- Bacteria
- Radiolaria
- Dinoflagellates
- Fungi
- Coelenterates and Ctenophores (jellyfish): siphonophores, medusae, soft corals, (comb jellies)
- Gastropods: nudibranchs (rare), clams (rare), squids, octopus (rare)
- Annelids (worms): polychaetes (bristle worms), earthworms
- Marine crustaceans: mysids (rare), copepods, ostracods (firefleas), amphipods, krill, shrimp Insects: beetles

(fireflies, glowworms), flies (rare), centipedes (rare), millipedes (rare)

- Echinoderms: sealilies, seastars, brittlestars, sea cucumbers
- Tunicates: pyrosomes, larvaceans
- Sharks (rare)

Bioluminescence has been demonstrated in cephalopods, copepods, ostracods, amphipods, euphausids, and many fish, annelids and jellies, to name but a few marine species. On land there are many types of bioluminescent insects, fireflies, glow-worms, click beetles, and some diptera, and there are many types of luminescent fungi responsible for glowing wood. The bioluminescent bacteria occur both terrestrially as well as marine. In only a few cases have the bioluminescence components from the various systems been characterized, and the overall chemistry established. Many, if not most luminous organisms in the deep sea, still remain to be investigated.

BIOCHEMISTRY OF LUMINESCENCE

The production of light in living organism is due to a chemi-luminescent reaction going on in the organism, the light termed is known as Chemiluminescence. The

Substrate in the Chemical reaction is Luciferin and the enzyme that catalyses the reaction is Luciferase. The chemical reaction that results in bioluminescence requires two unique chemicals: luciferin and either luciferase or photoprotein.

LUCIFERIN

Luciferin is the compound that actually produces the bioluminescent colour which is a result of the arrangement of luciferin molecules. Example: yellow in fireflies, green in lanternfish

Organisms that produce or synthesize luciferin on their own.

Example: Dinoflagellates

Bioluminescent dinoflagellates are a type of plankton, a tiny marine organism that can produce bluish-green colour which cause the surface of the ocean to sparkle at night.

Organisms that absorb luciferin from other organisms, in a symbiotic relationship or will take as food

Example: Midshipman fish

Midshipman fish obtain luciferin through the "seed shrimp" they consume.

Example: Squid

Many marine animals, such as squid, house bioluminescent bacteria in their light organs. The bacteria and squid have a symbiotic relationship.

LUCIFERASE

Luciferase is an enzyme. The interaction of the luciferase with oxidized (oxygen-added) luciferin creates the by product, called oxyluciferin which creates light. Bioluminescent dinoflagellates produce light using a luciferin-luciferase reaction. The luciferase found in dinoflagellates is related to the green chemical chlorophyll found in plants.

PHYSICAL NATURE OF BIOLUMINESCENCE LIGHT:

1. **Colour**: Mostly the bioluminescence light is blue, green, bluish green and yellow. Rarely red and orange colour also noted in some species.
2. **Intensity of the colour:** The intensity of the light is very low. Therefore, it is called as cold-light.

3. **Visual Efficiency**: Compared to human eye, the efficiency of light is high. The bioluminescence light is not at all physically different from other lights. This light can affect the photographic plates and can induce chemical reaction.
4. **Wave Length:** The wave length of the bioluminescence light is within the visible range.

TYPES OF BIOLUMINESCENCE

1. Extracellular Bioluminescence
2. Intracellular Bioluminescence
3. Symbiotic Bioluminescence

1.Extracellular Bioluminescence:

In Extracellular Bioluminescence, the luminous is discharged outside the organisms. This kind of Bioluminescence is seen mainly in marine invertebrates and very rare in terrestrial organisms.

(a) Example for organism that exhibit luminous slime all over the body is Balanoglossus.

(b) Example for organism that exhibit as luminescent cloud is Fire worm Odontosyllis, bivalve Pholas dactylus and pelgic Shrimps.

In the extracellular luminescence producing organism the photocytes are elongated flask or cups - shaped cells. They usually occur as patches of unicellular glands interspersed with mucus cells. Sometimes they are grouped into compact masses and from the masses a common duct arises, which opens out. In Chaetopterus they are located in the epidermal epithelial layer. In pelagic shrimps they are coelomic.

2. Intracellular Bioluminescence:

In Intracellular Bioluminescence, the luminous is produced internally in photophores. The organisms will have photogenic cells or photogenic granules. Some of the photophores look very much like eyes, but instead of retinal layer there is a photogenic light transmitting surface.

It occurs in terrestrial and aquatic organism. The light is produced intracellularly in photophores or in photogenic cells. In the protozoans there are no photophores but their photogenic granules. Intracellular luminescence is

common among Noctiluca, Ctenophora, Polyne, Ophiothrix, Stomias, Photostomias, etc.

3.Symbiotic Bioluminescence:

In some organisms, symbiotic bacteria will grow in special tissue sacs. These sacs are provided with reflectors, lenses and pigment curtains to control the emission of light. These bacteria will produce luminescence rarely, which will be exhibited by the organism. It is restricted to decapods, Cephalopods such as Loligo, Spirula etc. and teleost fishes such as Monocentris, Photoblepharon, Anomalops, Ceratias etc. In the fishes, the organ is a conspicuous and elongated tubular structure, situated just below the eye.

DIFFERENCE BETWEEN BIOLUMINESCENCE AND FLUORESCENCE:

S.No	BIOLUMINESCENCE	FLUORESCENCE
	Bioluminescence is a chemical reaction	Fluorescence does not involve a chemical reaction
	Bioluminescence is production and emission of light by a	A stimulating light is absorbed and re-emitted

	living organism	
	Bioluminescence is visible when the luciferase enzyme act on luciferin	The fluorescing light is only visible in the presence of the stimulating light
	Example: Fire Flies	Example: The ink used in highlighter pens is fluorescent.

PHOSPHORESCENCE:

Phosphorescence is similar to florescence, except the phosphorescent light is able to re-emit light for much longer periods of time.

Example: Glow-in-the-dark stickers are phosphorescent.

BENEFITS OF BIOLUMINESCENCE - IN NATURE:

1. To attract the prey

The organisms use their luminescent part to lure prey towards their mouths.

Example: Angler fish, Dragonfish, Loosejaws jelly. These organisms emit red light to attract the prey towards them.

2. For Defence:

The organisms use their luminescent part to protect themselves from the predators.

Example:

(a) Squid and shrimp produce a luminescent glowing cloud to protect themselves from their Predators. It will be similar in function to the ink cloud.

(b) Scale worms and brittle stars sacrifice a part of the body, which continues to flash even after detaching from the body.

(c) Some species of sea cucumber can break off the luminescent parts of their bodies onto nearby fish

(d) Hatchet fish - light producing organs that point downward

3. To Attract their Sex Mates:

The organisms use their luminescent part to attract their sex partners.

Example:

(a) The male Caribbean ostracod, a tiny crustacean, uses bioluminescent signals on its upper lips to attract its female partner.

(b) Syllid fireworms use bioluminescence to attract males while moving around in circles.

(c) Anglerfish, flashlight fish and pony fish all are thought to luminesce in order to tell the difference between males and females

BENEFITS OF BIOLUMINESCENCE - TO HUMANS:

(a) The beautiful colors and light that are produced by bioluminescence organisms can be works of art for humans. Some artists use the bacteria itself to create line drawings or entire exhibits with petri dishes.

(b) Used as a tool by researchers. Edie Widder, a scientist who specializes in bioluminescence, captured a live giant squid for the first time on film in 2012.

BENEFITS OF BIOLUMINESCENCE – IN BIOTECHNOLOGY:

(a) Environmental monitoring

(b) Remedial investigations

(c) Toxicity assessments

BENEFITS OF BIOLUMINESCENCE – IN BIOLOGY AND MEDICINE:

(a) Monitoring of biological processes (e.g. gene expression, protein–protein interaction and disease progression) with clinical, diagnostic and drug discovery applications

(b) Biomedical research using bioluminescence imaging

(c) Bioluminescent activated destruction is an experimental cancer treatment

(d) Light production: University of Wisconsin–Madison is researching the use of genetically engineered bioluminescent E. coli bacteria, for use as bioluminescent bacteria in a light bulb. In 2016, Glowee, a French company started selling bioluminescent lights. They used bacteria called *Aliivibrio fischeri* which glow in the dark but the maximum lifetime of their product was three days.

COMPUTATIONAL BIOLUMINESCENCE:

The recent and rapid evolution of fast computational technology underlies advances in many areas of Science. Starting more than fifty years ago, *ab initio* methods were used to calculate the total energy of small molecular systems. By *ab initio* is meant that the properties taken for solution of the Schroedinger equation for a system were the charges on the nuclei and separately the electron

orbitals. As the energy of a system of more than two interacting bodies cannot be solved analytically the method that has to be employed for molecular systems is that of "successive approximation". Initially each atom and its orbitals are positioned say, according to the spatial structure determined by X-ray crystallography, and the total energy, called the Hamiltonian H, calculated considering the force field assumption, e.g., the Coulombic attractions and repulsions, the various strengths of bond stretching and bending, and the quantum mechanical correlations among the electronic orbitals. Then the atomic positions are perturbed slightly and H recalculated, and this repeated many times until achieving a lowest energy solution. This process is called "Self-Consistent Field".

BEHAVIOUR

INTRODUCTION:

Behaviour is fundamental to living organisms. Animals with body architecture ranging from the cellular (i.e., sponges) to organ system (i.e., arthropods, echinoderms, and chordates) respond to stimuli from the internal and external environment.

Behaviour is defined as a response to a stimulus in order to achieve some definite purposeful goal. Whatever a living organism perform in response to a stimulus is behaviour. It includes feelings, attitudes, thoughts and mental processes. Also, it includes the reaction of living organism to the changes of the environment situations. In living organism's behaviour is controlled by the nervous system. Aristotle was the pioneer in the field of behaviour. Ethology is a field of basic biology, focuses on the behaviours of diverse organisms in their natural environment. Behavioural biology is the study of the biological and evolutionary bases for behaviour. Modern behavioural biology draws on work from the related but distinct disciplines of ethology and comparative psychology.

DEFINITION:

Behaviour is defined as a response to a stimulus in order to achieve some definite purposeful goal which is controlled by the nervous system.

EXAMPLES:

1. Orientation of plants towards the sun and wind– Ex: Sunflower, Lotus, Daffodils
2. Response of animals when placed on a hot surface – Ex: Ants
3. Hibernation of animals – Ex: frog, Bear, Squirrels
4. Bacteria actively move in response to chemical gradients
5. Amoebas change body shape to wrap around food

HISTORY

The origins of the scientific study of animal behaviour lie in the works of various European thinkers of the 17th to 19th centuries, such as British naturalists John Ray and Charles Darwin and French naturalist Charles LeRoy. These individuals appreciated the complexity and apparent purposefulness of the actions of animals, and they knew that understanding behaviour demands long-term observations of animals in their natural settings. At first, the principal attraction of natural history studies was to confirm the ingenuity of God. The publication of Darwin's On the Origin of Species in 1859 changed this attitude. In his chapter on instinct, Darwin was concerned with whether behavioural traits, like anatomical ones, can

evolve as a result of natural selection. Since then, biologists have recognized that the behaviours of animals, like their anatomical structures, are adaptations that exist because they have, over evolutionary time (that is, throughout the formation of new species and the evolution of their special characteristics), helped their bearers to survive and reproduce.

TYPES:

The behaviour is broadly classified into two groups,

1. STEREOTYPED BEHAVIOUR

When a particular type of stimulus produces the same kind of response in the whole life, the behaviour is called stereotyped. Stereotyped behaviour is exhibited by lower organisms.

Stereotyped behaviour is the outcome of inherited properties of the nervous system of the organism. Hence it is also called as inborn or innate or inherited behaviour. Higher organisms also show innate behaviour.

The stereotyped behaviour is further divided into 5 groups namely tropism, taxis, kinesis, reflexes and instincts.

2. VARIABLE BEHAVIOUR

When a particular type of stimulus produces different kinds of responses at different times, the behaviour is called variable. Here the responses are modified through experience, learning and reasoning. This type of behaviour is exhibited by higher organisms.

The variable behaviour includes learned or conditional behaviour. The learned behaviour includes habituation, conditional reflexes (associative learning), selective learning or trial and error learning, imprinting and reasoning.

CLASSIFICATION OF BEHAVIOUR:

1. Tropism
2. Taxis
3. Kinesis
4. Reflexes
5. Learned behaviour

TROPISM:

Definition:

Tropism is a phenomenon where only a part of the organism moves in response to a stimulus. It represents a fixed kind of behaviour. The concept of tropism was introduced in 1832 by the botanist, Augustin De Candole. Mostly, plants exhibit behaviour which is associated with tropism.

Example: Phototropism, geotropism.

Phototropism is the phenomenon where a part of the organism moves in response to light.

Geotropism is the phenomenon where a part of the organism moves in response to gravity.

When the movement is towards the source of stimulus, it is termed positive tropism.

When the movement is away from the source of stimulus, it is termed negative tropism.

For example, positive phototropism is exhibited by the movement of the flagellum of Euglena. Negative phototropism is exhibited by the movement of tubicolous worms (annelid worms).

TYPES OF TROPISM BASED ON STIMULUS:

Phototropism:

Sunlight has evolved as a stimulus for many organisms. Photosynthetic animals produce their food from sunlight. These organisms move towards the light. This positive phototropism causes organisms to move toward the light.

Example:

Many algae, plankton, and small invertebrates exhibit positive phototaxis.

Even organisms that are not photosynthetic have developed this tropism, which moves them to the same water column as their prey items. Other organisms may exhibit a negative reaction to light, and try to move away from it. Think of a beetle when you uncover it from its hiding place. The beetle will seek darkness, as darkness usually means safety. This tropism has the same stimulus but the opposite direction of the tropism in plants.

Heliotropism:

A similar phenomenon occurs in plants. Terrestrial plants are restricted in their movements, due to their roots.

Instead, plants orient their leaves toward the sun, to collect the most sunlight. This tropism is similar to phototropism, but the position of organism cannot change. Instead, the plant turns its leave by reducing or increasing turgor pressure, or water pressure, in individual cells. This can be seen in many crops, such as sunflowers, corn, and even garden flowers. Following the trajectory of the sun ensures that the plants receive the maximum amount of light.

Chemotropism

A widely spread tropism in the animal kingdom is chemotropism, or the tendency to turn or move towards or away from a specific chemical substance. Some single-celled organisms use different chemotropisms for different purposes. For example, one chemical might signal a mate, while another signals a dangerous or unpleasant area. These simple organisms will simply move towards or away from stimuli in the direction that has been most evolutionarily rewarding to their ancestors. In higher organisms, certain chemicals still attract animals, though they may not always move towards it. In other words, while they have the tropism, they do not always exhibit

taxis. For instance, sharks have a positive chemotropism for blood, or they tend to move towards blood. However, a shark will often inspect a meal or test it before devouring the prey, showing that other mechanisms can override a tropism.

Forms of tropism:

Phototropism - response to light

Geotropism - response to gravity

Chemotropism - response to particular substances

Hydrotropism - response to water

Thigmotropism - response to mechanical stimulation

Traumatotropism - response to wound lesion

Galvanotropism / Electrotropism - response to electric current

Types of tropism based on Structural alteration:

Orthotropic – movement will be towards the source of the stimulus

Plagiotropic - movements are tilted to the direction of stimulus

Diatropic - movements are at right angles to the direction of stimulus

TAXIS:

Definition:

Taxis is defined as the directed orientation movement of a motile organism in response to a stimulus.

Types:

1. Positive taxis
2. Negative taxis

Positive taxis:

When the movement is towards the stimulus, the taxis is called positive taxis.

Example: Eugelina and Ranatra move towards the source of light.

Negative taxis

When the movement is away from the stimulus the taxis is called negative taxis.

Example: Planarians, earthworms and copepods move away from the source of light.

Based upon the nature of stimulus, the taxis is classified into the following sub-types.

1. Thermotaxis: Directed orientation movement in response to temperature is called thermotaxis.
2. Phototaxis: Phototaxis is the movement in response to the stimulus of light.
3. Thigmotaxis: Movement in response to contact is called thigmotaxis.
4. Chemotaxis: Movement in response to chemicals is called chemotaxis.
5. Geotaxis: Geotaxis is the movement of an animal in response to stimulus of gravity.
6. Rheotaxis: Directed orientation movement in response to water current is called rheotaxis.
7. Telotaxis: Goal-directed movement. This describes the motion of visual predators who can see a distant visual signal and move to attack.
8. Klinotaxis refers to movement through a gradient while taking successive samples of the environment.
9. Magnetotaxis: Orientation in response to magnetic cues. Wide varieties of animals use magnetic cues to navigate. Aquaspirillum bacteria burrow in the mud, and use the magnetic field of the earth to determine position. In the Northern Hemisphere, they direct themselves to the

northern magnetic pole, which is actually the geographical South Pole, and so burrow down into the mud. In the Southern Hemisphere, they orient towards the geographical North Pole, which is a magnetic south pole.

10. Galvanotaxis: Movement in response to electric current is called galvanotaxis.
11. Tropotaxis: Turned movement. This refers to taking signal samples from paired receptors. Animals taking samples from paired receptors often zigzag about the trail. An experiment by Martin and Lindauer revealed that crossing the antennae in honeybees results in the bees traveling in the opposite direction from where the trail would lead them.
12. Menotaxis: Animal maintaining a constant angle to a stimulus. The Silkworm moth, for instance, flies at an angle perpendicular to the direction of the wind in order to pick up a scent trail. Once the moth detects the trail, it turns upwind to find the chemical gradient of the trail. Another type of menotaxis is sun compass orientation. Many animals use the position of the sun to orient themselves. These animals can compensate for the sun moving across the sky over the course of the day.

Honeybees for instance, imprint on the arc of the sun. They can utilize polarized light, and so they can locate the position of the sun even on an overcast day.

13. Mnemotaxis: Memory movement. This describes navigation through the use of landmarks. Many birds navigate using landmarks, as do salmon. Humans also use mnemotaxis when navigating through the use of street signs and familiar buildings.
14. Aerotaxis: Movement of an organism either towards or away from a region of higher oxygen content. Example: Aerobic Bacteria
15. Hydrotaxis: Movement of an organism in response to moisture or water. Example: Larvae of some insect species, wireworms move to deeper, more moister layers of the soil when the top layers dry out.

KINESIS:

Definition:

Kinesis is a phenomenon where the speed or velocity of locomotion of an organism is influenced by a stimulus. When the speed of an organism is influenced by the light stimulus, the kinesis is termed photokinesis.

Examples:

1. The larvae of mussel crab Pinnotheres move faster when exposed to increased light.
2. Locusts (insects) stop their flight when the sun is hidden by the clouds.
3. The movements of flies are greatly influenced by the wave length of light (Bertholf).

TYPES:

1. **ORTHOKINESIS** is a form of kinesis in which the speed of movement of the individual depends upon the intensity of the stimulus. An increase in the speed of movement is a positive orthokinesis whereas a decrease in the speed is referred to as negative orthokinesis.

2. KLINOKINESIS is another form of kinesis wherein the frequency or rate of turning is proportional to the intensity of the stimulus.

3. **CHEMOKINESIS** is the non-oriented or random movement of a motile cell to a soluble chemical.

4. **SYNKINESIS** is the involuntary movement accompanying a voluntary one, as the movement of a closed eye following that of the

uncovered one, or the movement occurring in a paralysed muscle accompanying motion in another part.

5. **METAKINESIS** is Moving apart. The separation of the two chromatids of each chromosome and their movement to opposite poles in the anaphase of mitosis.

6. **STATHMOKINESIS** is a condition of arrested mitosis after treatment with an agent, such as colchicine, which effectively alters the mitotic spindle to prevent typical rearrangement of the chromosomes preceding cell division.

7. **ALLOKINESIS** is passive or reflex movement; involuntary movement.

8. **LYMPHOKINESIS** is the circulation of lymph in the lymphatic vessels and through the lymph nodes. Also, the movement of endolymph in the semicircular canals of the inner ear.

REFLEX

Definition:

Reflex is the response of a part of body. Reflex mechanisms constitute one of the major modes of adaption in the animal kingdom.

Examples:

1. The winking of the eye when a particle of dust touches the eyelids.
2. Act of sneezing and coughing.
3. The sudden withdrawal of one's hand when it comes in contact with hot surface.

Classes of Reflexes:

1. Tonic reflexes:

Tonic reflexes are relatively slow and long-lasting adjustments. These reflexes maintain muscular tone, posture and equilibrium.

2. Phasic reflexes:

Phasic reflexes are rapid and short-lived adjustments. This can be seen in the flexion response.

LEARNING:

Definition:

Learning or learned behaviour involves the previous experiences of an individual. This will usually bring about a lasting change in behavioural patterns, rather than a permanent change in behaviour, because forgetting occurs in learned behaviour. In flat worms a simple kind of learning seems to occur. Among other animal groups, individuals vary in their abilities to learn. This is of

common occurrence among humans as well as other organisms. Some species can learn certain things faster than other related types.

Learning is the process of acquiring new understanding, knowledge, behaviours, skills, values, attitudes, and preferences. The ability to learn is possessed by humans, animals, and there is also evidence for some kind of learning in certain plants. Some learning is immediate, induced by a single event (e.g. being burned by a hot stove), but much skill and knowledge accumulate from repeated experiences. The changes induced by learning often last a lifetime, and it is hard to distinguish learned material that seems to be lost from that which cannot be retrieved. Human learning starts at birth and continues until death as a consequence of ongoing interactions between people and their environment. The nature and processes involved in learning are studied in many fields, including educational psychology, neuropsychology, experimental psychology, and pedagogy. Research in such fields has led to the identification of various sorts of learning. For example, learning may occur as a result of habituation, or classical conditioning, operant

conditioning or as a result of more complex activities such as play, seen only in relatively intelligent animals. Learning may occur consciously or without conscious awareness. Learning that an aversive event can't be avoided nor escaped may result in a condition called learned helplessness. There is evidence for human behavioural learning prenatally, in which habituation has been observed as early as 32 weeks into gestation, indicating that the central nervous system is sufficiently developed and primed for learning and memory to occur very early on in development.

TYPES:

The learned behaviour can be classified into the following types.

1. HABITUATION:

One of the simplest ways that animals learn is through habituation. Animals decrease the frequency of a behaviour in response to a repeated stimulus. This occurs when the behaviour does not result in some type of benefit or reward. Habituation has been demonstrated to occur in virtually every species of animal. It is adaptive because

responding to a stimulus when there is no benefit or reward is a waste of energy.

2. SENSITIZATION:

Sensitization is the opposite of habituation. In sensitization, an animal learns to react more often or more strongly to a repeated stimulus. For example, exposure to painfully loud sounds causes an animal to respond strongly. The animal may act agitated and try to escape from the source of the sounds. If the loud sounds are followed by lesser sounds that are not painful, the animal may respond to them just as strongly. If this occurs, the animal has become sensitized to sounds.

3. ASSOCIATIVE LEARNING:

Associative learning is the process by which a person or animal learns an association between two stimuli or events. In classical conditioning a previously neutral stimulus is repeatedly paired with a reflex eliciting stimulus until eventually the neutral stimulus elicits a response on its own.

4. SELECTIVE LEARNING OR TRIAL AND ERROR LEARNING:

If an animal learns slowly after several trials and errors, it is called trial-and-error learning or selective learning. This kind of learning involves either a reward or a punishment or both. B.F.Skinner devised a box for finding out trial-and-error learning. The box is provided with a small bar which when pressed will release a pellet of food in the cage. A hungry rat is placed inside the box. The rat begins to investigate the box and sooner or later strikes the bar. With the result the food is released. Soon the rat learns the fact that as a result the food is released. It also stops pressing the bar when the food supply is cut off. This device is used to study many aspects of learning. With animals that are capable of locomotion, learning can be studied by studied by means of a maze. A maze is basically a route with one or more choices of turns leading to a goal that is favourable or unfavourable to the animal. The simplest form of maze is the “T”-maze or “Y”-maze. At first an animal, placed inside a maze, explores blind alleys: as it learns the maze, the time to reach the “reward” is reduced.

5. INSIGHT LEARNING:

Several species of animals have been observed using insight learning. Insight learning is the use of past experiences and reasoning to solve problems. Unlike operant conditioning, insight learning does not involve trial and error. Instead, an animal thinks through a solution to a problem based on previous experience. The solution often comes in a flash of insight. Insight learning requires relatively great intelligence. Species most likely to learn in this way include species of apes (chimpanzees, gorillas, and orangutans), crows, and humans. Examples of insight learning in apes in the wild include chimpanzees "fishing" for termites. The animals place a “tool” such as a twig in a hole of termite mound, and the termites crawl onto the twig. Then the chimpanzee withdraws the twig from the hole and eats the termites. Chimpanzees may also use leaves to sop up drinking water and rocks to smash nuts. They have even been observed sharpening sticks with their teeth and using them as spears to kill small animals for food. Gorillas may use tools to solve problems as well. For example, they have been observed using small branches as walking sticks and as measuring sticks to test the depth of

water before wading through it. Orangutans use small sticks to get at edible seeds inside prickly fruits without being pricked. They may also use leaves to make rain-hats and roofs over their sleeping nests.

6. IMPRINTING:

Imprinting is a simple and highly specific type of learning that occurs at a particular age or life stage during the development of certain animals, such as ducks and geese. When ducklings hatch, they imprint on the first adult animal they see, typically their mother. Once a duckling has imprinted on its mother, the sight of the mother acts as a cue to trigger a suite of survival-promoting behaviours, such as following the mother around and imitating her.

There are many other examples of imprinting in animals:

- Puppies must be exposed to humans within the first two or three months of life, or they will never become socialized and be suitable as human companions.
- In birds called zebra finches, chicks raised with another species of bird, rather than with other zebra finches, will imprint on birds of the other species. As adults, the finches

will try to mate with birds of the other species instead of with other zebra finches.

7. REASONING:

Reasoning is best described in an example by Koehler. He placed some wooden boxes on the floor of a room and a bunch of bananas hanging from the roof. When chimpanzees were allowed inside the room, without any trial and error they began to pile the wooden boxes one above the other and climbing to the top they reached the bananas. This kind of tool-using reasoning behavioural pattern is restricted among mammals.

8. CLASSICAL CONDITIONING:

In classical conditioning, a response already associated with one stimulus is associated with a second stimulus to which it had no previous connection. The most famous example of classical conditioning comes from Ivan Pavlov's experiments in which dogs were conditioned to drool—a response previously associated with food—upon hearing the sound of a bell. As Pavlov observed, and as you may have noticed too, dogs salivate, or drool, in response to the sight or smell of food. This is something

dogs do innately, without any need for learning. In the language of classical conditioning, this existing stimulus-response pair can be broken into an unconditioned stimulus, the sight or smell of food, and an unconditioned response, drooling.

9. **OPERANT CONDITIONING:**

Operant learning is the basis of most animal training. The conditioned behaviour is continually modified by positive or negative reinforcement, often a reward such as food or some type of punishment, respectively. In this way, the animal is conditioned to associate a type of behaviour with the punishment or reward, and, over time, can be induced to perform behaviours that they would not have done in the wild, such as the "tricks" dolphins perform at marine amusement park shows.

10. OBSERVATIONAL LEARNING:

This type of learning involves observing the behaviour of another individual and either copying the behaviour or avoiding it. Most studies of observational learning have focused on behaviours that are copied.

Canadian psychologist Albert Bandura is world renowned for his investigations of observational learning in humans. According to Bandura, learning a behaviour by observing it in someone else requires four conditions to be met:

1. An individual (the observer) must pay attention to the behaviour of another individual (the model).
2. The observer must be able to remember what the model has done.
3. The observer must have the ability or skills to perform the behaviour.
4. The observer must be motivated and have the opportunity to perform the behaviour.

Because of these conditions, observational learning requires considerable intelligence and is found most often in humans. However, observational learning has also been observed in many other species of animal. For example, wolves and other predatory animals that hunt in packs learn hunting skills through observational learning. Young animals observe and copy the behaviour of older animals when they hunt together.

11. PLAY:

Play is one way that young animals develop the skills needed during adulthood. Play has risks and costs. It may increase exposure to predators and lead to injury. It also requires energy. For play to have evolved, it is likely to have significant benefits that outweigh these drawbacks. Play is actually a form of learning. Through play, young animals learn important skills. By chasing, pouncing on, and wrestling with one another, kittens and other young predators are learning how to catch prey. By running, leaping, and kicking their hind legs, young deer, zebras, and other prey animals are learning how to escape or ward off attacks from predators. Play can also be beneficial by helping young animals develop muscles and improve their physical fitness.

CONCLUSION:

Animal behaviour is the result of multiple interacting forces related to an individual's genes, physiology, and development and the internal and external environments in which they live. There is genetic variation among individuals of a population for behaviours related to

survival and reproduction. Successful behaviours are passed on to the next generation and may evolve over time.

TEMPERATURE REGULATION

INTRODUCTION:

Temperature Regulation or Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. A thermoconforming organism, by contrast, simply adopts the surrounding temperature as its own body temperature, thus avoiding the need for internal thermoregulation. The internal thermoregulation process is one aspect of homeostasis: a state of dynamic stability in an organism's internal conditions, maintained far from thermal equilibrium with its environment. If the body is unable to maintain a normal temperature and it increases significantly above normal, a condition known as hyperthermia occurs. Humans may also experience lethal hyperthermia when the wet bulb temperature is sustained above 35 °C for six hours. The opposite condition, when body temperature decreases below normal levels, is known as hypothermia. It results when the homeostatic control

mechanisms of heat within the body malfunction, causing the body to lose heat faster than producing it.

DEFINITION

Thermoregulation is a mechanism by which living organisms maintain body temperature by tightly controlled self-regulation, no matter the temperature of their surroundings. Temperature regulation is a process that biological systems use to preserve a stable internal state to survive.

ORGAN SYSTEMS INVOLVED

Multiple organs and body systems are affected when thermoregulation is not working correctly. During heat illness as a result of improper thermoregulation, the following organs and systems are impaired. Many of these issues cause or are influenced by the other issues.

- The heart experiences an increased burden due to elevations in heart rate and increased cardiac output.
- The circulatory system sustains intravascular dehydration.
- The brain suffers from cerebral ischemia and/or cerebral oedema.

- The gastrointestinal tract is vulnerable to haemorrhage and also sepsis because the mucosa of the intestines increases its permeability.
- The lungs suffer when Acute respiratory distress syndrome (ARDS) results from the increase of hyperventilation, hyperpnea, and pulmonary vasodilation.
- Acute renal failure can commence because of the dehydration and impairment in circulation.
- Liver cells suffer because of the fever, ischemia, and cytokines increase in the intestinal tract.
- Various organs can result in DIC and microthrombi.
- Electrolyte abnormalities are likely as well as hypoglycemia, metabolic acidosis, and respiratory alkalosis.

MECHANISM:

Thermoregulation has three mechanisms:

- afferent sensing
- central control
- efferent responses.

There are receptors for both heat and cold throughout the human body. Afferent sensing works through these receptors to determine if the body is experiencing either

too hot or too cold of a stimulus. Next, the hypothalamus is the central controller of thermoregulation. Lastly, efferent responses are carried out primarily by the body's behavioural reactions to fluctuations in body temperature.

Example: If a person is feeling too warm, the normal response is to remove an outer article of clothing. If a person is feeling too cold, they choose to wear more layers of clothing. Efferent responses also consist of automatic responses by the body to protect itself from extreme changes in temperature, such as sweating, vasodilation, vasoconstriction, and shivering

CLASSIFICATION OF ANIMALS BASED ON THERMOREGULATION

CLASSIFICATION- 1

Based on thermoregulation, animals are classified into two major groups. They are as follows:

1. POIKILOTHERM:

A poikilotherm is an animal whose internal temperature varies considerably. It is the opposite of a homeotherm, an animal which maintains thermal homeostasis. While the term in principle can apply to all organisms, it is generally

only applied to animals, and mostly to vertebrates. Usually the fluctuations are consequence of variation in the ambient environmental temperature. Many terrestrial ectotherms are poikilothermic. Some ectotherms remain in temperature-constant environments to the point that they are actually able to maintain a constant internal temperature (i.e. are homeothermic). It is this distinction that often makes the term "poikilotherm" more useful than the vernacular "cold-blooded", which is sometimes used to refer to ectotherms more generally.

Poikilotherms are also called "ectotherms" or "cold-blooded animals." Such creatures are the thermoregulatory opposites of "endotherms" or "homeotherms" - better known to most of us as "warm-blooded animals" - which are able to maintain a fairly high and constant body temperature relatively independent of the temperature of the surroundings.

Poikilothermic animals include types of vertebrate animals, specifically some fish, amphibians, and reptiles, as well as many invertebrate animals. The naked mole-rat and sloth are some of the rare mammals which are poikilothermic.

PHYSIOLOGY:

Poikilotherm animals must be able to function over a wider range of temperatures than homeotherms. The speed of most chemical reactions varies with temperature, and in order to function poikilotherms may have four to ten enzyme systems that operate at different temperatures for an important chemical reaction. As a result, poikilotherms often have larger, more complex genomes than homeotherms in the same ecological niche. Frogs are a notable example of this effect, though their complex development is also an important factor in their large genome. Because their metabolism is variable and generally below that of homeothermic animals, sustained high-energy activities like powered flight in large animals or maintaining a large brain is generally beyond poikilotherm animals. The metabolism of poikilotherms favours strategies such as sit-and-wait hunting over chasing prey for larger animals with high movement cost. As they do not use their metabolisms to heat or cool themselves, total energy requirement over time is low. For the same body weight, poikilotherms need only 5 to 10% of the energy of homeotherms.

2. HOMEOTHERMIC ANIMALS OR THERMO REGULATORS

In some animals the body temperature remains constant and it is independent of environmental temperature. These animals are called homeothermic animals. When the environment is cold the blood of these animals will be at a higher temperature. Hence these animals are also called warm-blooded animals. They can regulate their body temperature by generating heat through metabolic activities. Hence, they are also called endothermic animals. Eg: Birds and mammals.

CLASSIFICATION- 2

Based on the source of body heat, animals are classified into three types, namely ectotherms, endotherms and heterotherms.

ECTOTHERMS

Ectotherms are animals depending on their surroundings for the source of body heat. Eg: All animals except birds and mammals.

The ectotherms have the following salient features:

1. In ectotherms, the body temperature passively adjusts with the surrounding (ambient) temperature.
2. They have low rates of metabolic heat production.
3. They have high thermal conductance and are poorly insulated.
4. As a result, the heat derived from metabolic processes is quickly lost to the surroundings.
5. The high thermal conductance allows the ectotherms to absorb heat readily from their surroundings.
6. They regulate their body temperature by behavioural temperature regulation.

ENDOTHERMS

Endotherms are animals which generate heat on their own body. Eg: Birds, mammals, a few lower vertebrates and some insects.

The endotherms have the following salient features:

1. The endotherms maintain their body temperature well above the ambient (=surrounding) temperature in cold climates.
2. They have high rates of metabolic heat production.

3. The metabolic rate of an endotherm at rest is at least 5 times that of an ectotherm of equal size.
4. They are well insulated with feathers and fur.
5. They regulate their body temperature by thermogenesis.

HETEROTHERMS

Heterotherms behave like ectotherms and endotherms. Like endotherms they generate body heat. Like ectotherms they cannot maintain (regulate) the body temperature within a narrow range.

Example:

Many flying insects, tunas, mackerels, mako sharks, pythons, Echidna, camel.

Types:

Heterotherms are of two types, namely temporal heterotherms and regional heterotherms.

1. Temporal Heterotherms:

Some animals maintain varying temperatures at different times. These animals are called heterotherms. Example:

1.Flying insects, pythons, mackerels, etc., raise their body temperature well above the ambient temperature by muscular activity. Some insects prepare for flight by exercising their flight muscles for a time to raise their temperature before take-off.

2.On a hot day, the camel absorbs heat and allows its body temperature to go high up. At night, it allows its body temperature to drop several degrees below normal. Thus, the camel is a temporal heterotherm.

2. Regional Heterotherms:

These are poikilotherms which maintain different regions of the body.

Example:

Many flying insects, tuna, mako sharks, etc. They maintain high temperature in the core (deeper part of the body) and low temperature in the periphery.

THERMOREGULATORY MECHANISMS:

Animals gain or lose heat from the body or external environments. So, the body temperature tends to increase or decrease. But a preferred temperature or optimum temperature is essential for comfortable life and maximum

physiological activity. The animals developed a variety of mechanisms and adaptations to maintain an optimum temperature.

They are as follows:

- Hibernation
- Aestivation
- Thermal Migration
- Basking
- Fluttering of Wings
- Antifreeze Substances
- Regulation of Blood Flow in Ectotherms
- Increase in Body Size
- Sub-cutaneous Fats, Fur and Feathers
- Counter current Heat Exchange System
- Thermogenesis (Heat Production)
- Increased Metabolism
- Acceleration of Thyroid Activity
- Vasoconstriction and vasodilation
- Sweating and Panting

HIBERNATION:

Introduction:

The term hibernation is commonly applied to all types of winter dormancy in vertebrate animals. Hibernators include many fishes, amphibians, and reptiles that overwinter with body temperatures near freezing, as well as bears and a few other mammals that spend most of the winter sleeping in dens. The latter, however, do not undergo much lowering of body temperature and are rather easily awakened; they are not considered true hibernators. The true hibernator spends most of the winter in a state close to death; in fact, the animal may appear to be dead. The body temperature is close to 0° C (32° F); the respiration is only a few breaths per minute; and the heartbeat is so slow and gradual as to be barely perceptible. Exposed to moderate warmth, the animal slowly awakens, requiring an hour or more to reach an alert state.

Definition:

Hibernation is a deep sleep that helps them to save energy and survive the winter without eating much.

Examples:

Small mammals, such as chipmunks, dormice, hamsters, hedgehogs and bats. Also, many insects, amphibians and reptiles.

Dangers of Hibernation:

Animals may die during hibernation from,

- lack of fat
- severe weather
- premature awakening

AESTIVATION:

Example:

Many terrestrial and aquatic animals, including lungfish, earthworms, snails, amphibians and reptiles, including Nile crocodiles.

Dangers of Aestivation:

Large numbers of aestivating animals perish in periods of prolonged drought.

DIAPAUSE:

Introduction:

Diapause, spontaneous interruption of the development of certain animals, marked by reduction of metabolic activity. This period of suspended development is an apparent response to the approach of adverse environmental conditions. It may occur during any life stage but is most common among pupae (*e.g.*, the cocoons of moths). Diapause sets in when the bodily concentrations of growth and molting hormones decrease, which usually coincides with changes in day length, temperature, or abundance of food. Diapause is genetically determined but may be eliminated experimentally if the animals are raised under constant and favourable environmental conditions.

Examples:

Many insects and mites, a few crustaceans and snails, and perhaps certain other animal groups.

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